ESTCP
Cost and Performance Report

(SI-0401)

Implementation and Commercialization of New Plant Germplasms for Use on Military Ranges

July 2009

ENVIRONMENTAL SECURITY
TECHNOLOGY CERTIFICATION PROGRAM

U.S. Department of Defense

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **JUL 2009**	2. REPORT TYPE	3. DATES COVERED **00-00-2009 to 00-00-2009**

4. TITLE AND SUBTITLE **Implementation and Commercialization of New Plant Germplasms for Use on Military Ranges**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Environmental Security Technology Certification Program (ESTCP),4800 Mark Center Drive, Suite 17D08,Alexandria,VA,22350-3605**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**90**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

COST & PERFORMANCE REPORT
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ACRONYMS AND ABBREVIATIONS

ACOM	U.S. Army Commands
AEC	Army Environmental Command
AOSCA	Association of Official Seed Certifying Agencies
ARS	Agricultural Research Service
BLM	Bureau of Land Management
CERL	Construction Engineering Research Laboratory
CRREL	Cold Regions Research and Engineering Laboratory
2,4-D	2,4-dichlorophenoxyacetic acid
DoD	Department of Defense
DPG	Dugway Proving Ground
ECAM	Environmental Cost Analysis Methodology
ERDC	Engineer Research and Development Center
ESTCP	Environmental Security Technology Certification Program
FF	fine fescues
FORSCOM	Forces Command
FRRL	Forage and Range Research Laboratory
HG	hairgrass
INRMP	Integrated Natural Resources Management Plan
ITAM	Integrated Training Area Management
kPA	kilo Pascal
kg/ha	kilograms per hectare
lbs/A	pounds per acre
LSD	least significant difference
MRTFB	Major Range Test Facility Base
NGB	National Guard Bureau
NPA	Northern Plains Area
NRCS	Natural Resources Conservation Service
ns	not significant
PLS	pure live seeds
PVP	plant variety protection
ROD	Record of Decision

ACRONYMS AND ABBREVIATIONS (continued)

SERDP	Strategic Environmental Research and Development Program
SG	Switchgrass
SI	Sustainable Infrastructure
SRP	Sustainable Range Program
t/ha	tonnes per hectare
tons/A	tonnes per acre
USDA	U.S. Department of Agriculture
WL	Weeping lovegrass
WYARNG	Wyoming Army National Guard
YTC	Yakima Training Center

TERMINOLOGY

Breeders, Foundation, and Certified Seed. Breeders seed is produced from the last cycle of selection. This seed is used to produce foundation seed, which, in turn, is used to establish certified seed fields from which seed is produced for commercial sale.

Cultivar versus Germplasm. Plant materials developed in this project were released as "cultivars" or a level of pre-variety "germplasm." A cultivar (sometimes called a variety) is a population that is unique for selected traits and that has undergone multiple cycles of selection and extensive testing over multiple locations. A cycle refers to a complete generation from seed to plant (selection) to seed. Cultivars are genetically stable. A germplasm (pre-cultivar) can be a single genotype or a collection of multiple genotypes from multiple origins that are unique for a given character but have not undergone or met the more rigorous requirements for a cultivar. Germplasms may be released as one of three levels—source-identified, selected, or tested class—depending on the level of selection or testing.

Introduced versus Naturalized versus Native Species. In this report, we use the term "introduced" to represent species not indigenous to North America. Many of the introduced plant materials on western rangelands, including those in this project, originated in Central Asia where they occur in very diverse ecosystems. The superior stand-establishment characteristics, hardiness, wide adaptability, persistence under grazing, availability and lower cost of seed, and productivity of introduced perennial species compared with indigenous native species have been documented in many regions (Barker et al., 1977; Vallentine, 1977; Kilcher and Looman, 1983; Lawrence and Ratzlaff, 1989). Like their native counterparts, introduced grasses have the capacity to sort by natural selection and improve their adaptation to the environmental conditions on sites where they are seeded. As a result, many of the introduced species included in the project are naturalized, having existed in stands for over 50 years. These naturalized species have co-existed with native flora on North American rangeland (both private and public) for years. Within this report, we use only the terms "introduced" and "native," based on the species origin.

Invasive. For the purposes of this study, we defined an invasive species as an introduced species that will spread beyond the areas it currently inhabits and prevent the establishment of desired perennial plants. We do not agree with definitions of invasive that equate it to any introduced or exotic species. Tiller and rhizome development and seedling encroachment through seed dispersal are potential indicators of invasiveness. Except for "RoadCrest" crested wheatgrass, which is moderately rhizomatous and is best suited for cantonments and roadsides, we did not use any introduced species displaying these characteristics. On the other hand, rhizome development is valuable in desired native species for land stabilization and reclamation of disturbed lands. We worked with some rhizomatous natives to improve establishment and persistence of desired species.

Resiliency. We define resilient grasses as those better able to withstand training without being permanently damaged. This trait can be accomplished in two ways. Plants that establish more quickly will be larger and therefore more capable of withstanding training. Also, plants that can recover after being trained on (i.e., via rhizome spread) can adjust to changes in land use and maintain a vegetative sward.

LIST OF PLANT SPECIES USED IN PROJECT

Common Name	Scientific Name	Range Relative to U.S.
Alfalfa	*Medicago sativa*	Introduced
Basin wildrye	*Leymus cinereus* (Scribn. & Merr.) Á. Löve	Native (western U.S.)
Beardless wildrye	*Leymus triticoides* (Buckley) Pilg.	Native (western U.S.)
Bering hairgrass (HG)	*Deschampsia beringénsis*	Native (northeastern and western U.S.)
Big sagebrush	*Artemisia tridentata*	Native
Bluebunch wheatgrass	*Pseudoroegneria spicata* (Pursh) A. Löve	Native (western U.S.)
Blue gramma	*Bouteloua gracillis*	Native (western U.S.)
Buffalograss	*Bouteloua dactyloides* (Nutt.) J.T. Columbus	Native (midwestern U.S.)
Cheatgrass	*Bromus tectorum* L.	Introduced invasive weed
Crested wheatgrass (Fairway type)	*Agropyron cristatum* (L.) Gaertn.	Introduced
Crested wheatgrass (Standard type)	*Agropyron desertorum* (Fisch. ex Link) Schult.	Introduced
Forage kochia	*Kochia prostrata* sp. virescens	Introduced shrub
Hard fescue	*Festuca brevipila* R. Tracey	Introduced
Kentucky bluegrass	*Poa pratensis L.*	Native (northern U.S.)
Little bluestem	*Schizachyrium scoparium* (Michx.) Nash var. *scoparium*]	Native
Medusahead rye	*Taeniatherum asperum* (Simonk.) Nevski	Introduced invasive weed
Purple needlegrass	*Nassella pulchra* (Hitchc.) Barkworth	Native (California)
Russian wildrye	*Psathyrostachys juncea* (Fisch.) Nevski	Introduced
Sandberg bluegrass	*Poa secunda* J. Presl	Native (western U.S.)
Sheep fescue	*Festuca ovina* L.	Introduced
Siberian crested wheatgrass	*Agropyron fragile* (Roth) P. Candargy	Introduced
Slender wheatgrass	*Elymus trachycaulus* (Link) Gould ex Shinners	Native
Snake River wheatgrass	*Elymus wawawaiensis* ined.	Native (northwestern U.S.)
Switchgrass (SG)	*Panicum vergatum* L.	Native
Tall fescue	*Festuca arundinacea* Schreb.	Introduced
Thickspike wheatgrass	*Elymus lanceolatus* (Scribn. & J. G. Sm.) Gould	Native
Tufted HG	*Deschampsia cespitosa* (L.) P. Beauv.	Native (northeastern and western U.S.)
Weeping lovegrass (WL)	*Eragrostis curvula* (Schad.) Nees	Introduced
Western wheatgrass	*Pascopyrum smithii* (Rydb.) Á. Löve	Native (western U.S.)
Western yarrow	*Achillea millefolium* L.	Native forb

ACKNOWLEDGEMENTS

This report was prepared by Antonio J. Palazzo, Susan E. Hardy, and Timothy J. Cary, all of the Environmental Sciences Branch, U.S. Army Engineer Research and Development Center (ERDC), Cold Regions Research and Engineering Laboratory (CRREL), Hanover, NH, and by Dr. Kevin Jensen U.S. Department of Agriculture (USDA)-Agricultural Research Service (ARS), Logan, UT.

The report was prepared under the general supervision of Dr. Terrence Sobecki, Chief, Environmental Sciences Branch; Dr. Lance Hansen, Deputy Director; and Dr. Robert E. Davis, Director, CRREL.

The Commander and Executive Director of ERDC is Colonel Richard B. Jenkins. The Director is Dr. James R. Houston.

Funding for the project was provided through the Department of Defense (DoD) Environmental Security Technology Certification Program (ESTCP). The authors acknowledge Dr. Jeffrey Marqusee, ESTCP Director, and Drs. Robert Holst and John Hall, ESTCP Sustainable Infrastructure Program Managers, former and present, for financial and technical support. The authors also thank Kim Watts and Bonnie Packer, Army Environmental Command (AEC), for supporting additional aspects of this research, both financially and technically.

The authors also thank HydroGeoLogic, Inc., contractor for the ESTCP program, for technical and administrative support, including John Thigpen, Carrie Wood, Kristen Lau, Lucia Valentino, Sheri Washington, Jennifer Rusk, and Susan Walsh.

Over the life of this program the authors have enjoyed and benefited from working with many people, including Dr. David Huff, Pennsylvania State University, for technical assistance, and Dan Ogle and Loren St. John, U.S. Department of Agriculture (USDA)-Natural Resources Conservation Service (NRCS) Plant Materials Center, Aberdeen, ID, for seed production.

Many ERDC people have helped to make this program a success, including David Cate for editing the manuscript and Nancy Perron, Dennis Lambert, and Troy Arnold for technician support. William Severinghaus, Robert Lacey, Alan Andersen, Dick Gebhart, and Ryan Busby at ERDC-Construction Engineering Research Laboratory (CERL) provided technical support, and Gary Pasternak helped develop the memorandums of agreements between cooperating agencies.

Technical material contained in this report has been approved for public release.

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1.0 EXECUTIVE SUMMARY

1.1 BACKGROUND

The Department of Defense (DoD) must constantly balance its military mission and its commitment to stewardship on millions of acres of ranges and training lands. The military mission requires that vegetation, primarily grasses, be as resilient to military training activities as possible to maintain realism and control soil erosion. The military faces increasingly difficult land management challenges as weapons technology improves and training and testing needs change. Complicating this challenge is the impact of continuing development, especially urbanization, outside the boundaries of military installations. The military is also faced with the need to promote indigenous species and control undesirable and invasive species of its lands.

Before our efforts, there was little or no research on the genetics or wear-resiliency of low-maintenance rangeland plants. The prevalent method for controlling invasive plants on military lands was the use of herbicide applications, but these were reduced beginning in 2001. Research on pest or animal control of invasive plants is currently active in many public weed-control programs, but there is limited knowledge of the interrelationships of invasive and desirable plant species. To compete with the annual invasive or noxious weeds, sown species should germinate readily and have rapid growth rates soon after germination.

Our goals were both to develop plants more resilient to military training activities and to get native plants to establish more rapidly to return the land more quickly to military use. Through our Strategic Environmental Research and Development Program (SERDP) Project Sustainable Infrastructure (SI)-1103, we bred native and introduced grass and forb germplasms with improved establishment and seedling vigor (Palazzo et al., 2003). We addressed the potential invasiveness of the germplasms we were developing by convening an independent review panel at Yakima Training Center (YTC) in 1999; the panel concluded that the plants we were using were not encroaching into other plant communities and were not establishing monocultures (Palazzo et al., 1999). We also developed ecological-bridge seeding methods to further enhance the ability of our modified germplasms to establish viable native plant stands as rapidly as possible. In the ecological-bridge work, we used our investigations into root growth and establishment relationships among various species to select seed mixes of rapidly establishing introduced grasses and desired native grasses. The species of introduced grasses selected varies with climatic and land-use conditions, but the primary criterion is for this plant to be relatively short-lived so that a native vegetative stand is developed. When properly selected, the introduced grasses quickly protect the soil and create an environment in which the native grasses gradually establish and dominate the seeded stand.

Near the end of the SERDP project, we began some large-scale demonstrations and held a workshop for federal, state, and regional land managers as well as representatives of seed companies (Hardy and Palazzo, 2002). The goals of this Environmental Security Technology Certification Program (ESTCP) project were to further demonstrate and validate the germplasms and our seeding methods and to make the modified seeds available to land managers.

1.2 OBJECTIVES OF THE DEMONSTRATION

In our earlier SERDP project "Identify Resilient Plant Characteristics and Develop a Wear-Resistant Plant Cultivar for Use on Military Training Lands" (SI-1103), we bred native and introduced plants more resilient to military training activities and we developed seeding methods to further enhance the ability of our modified germplasms to establish viable native plant stands as rapidly as possible. Our objectives in this ESTCP project were to bring the new germplasms and modified seeding methods to widespread use on DoD and other federal lands by demonstrating and further validating the new plant materials and seeding methodologies, investigating the release of cultivars, initiating seed contracts, and developing a planting guide for military facilities in the Intermountain West (Palazzo et al., 2009). All of these objectives were met.

1.3 DEMONSTRATION RESULTS

Our modified germplasms may be used over a broad area of the Intermountain West Region of the United States. Through the demonstrations and evaluation in this ESTCP project, we have released four new cultivars (Jensen et al., 2006, 2007, 2009; Waldron et al., in press) and two pre-variety germplasms (Waldron et al., 2006a, 2006b). The release notices are a form of announcement that these plants have been developed and are available for production and distribution. The notices define the species and note how they are different from the more important cultivars or germplasms of this species currently on the commercial market.

Our seeding methods have proven successful on eastern and western ranges (Fort Drum, NY; YTC, Yakima, WA; and Fort Carson, CO). Our plants required no maintenance after seeding; plant stands continued to thrive throughout the demonstration. Seed of three grasses was distributed to eight military facilities in the Intermountain West over two years, and we have established one commercial seed contract. We have recently published a Planting Guide (Palazzo et al., 2009) to aid land managers in selecting the proper seed mixture for their varying environmental and land use needs.

The modified germplasms and establishment methods will reduce the overall need for herbicide applications in controlling noxious weeds at seeding time, and they will decrease the number of reseedings required in some situations, allowing training to resume more rapidly, increasing the diversity of species on military rangelands, and reducing the likelihood of sediment or runoff from erosion.

1.4 IMPLEMENTATION ISSUES

Military land managers are generally conservative about trying new things, and they face strong competition for funding with other military environmental requirements; many land managers will consider using new technology only if they can see it firsthand and understand how to implement it. The demonstrations provided applied information on the modified germplasms and seeding methods and were made available for inspection by land managers. Because there is no significant increase in cost to use our improved plants or seeding methods, the only other barrier to implementation of the technology would be the cost and availability of seeds of the improved varieties. To over come this, we contracted with the U.S. Department of Agriculture (USDA)-Natural Resources Conservation Service (NRCS) Plant Material Center in Aberdeen, ID, to

produce seed of three germplasms specifically for military facilities. About 5200 pounds of seed were produced in FY07 and FY08. Additional seed will be sold to commercial producers; one such sale resulted in 36,000 lb of “FirstStrike” slender wheatgrass seed for sale at a value of $270,000. To further increase awareness of our modified seeds and planting methods, we provided consultations and made presentations at conferences, workshops, and other appropriate forums and produced a planting guide (Palazzo et al., 2009).

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2.0 INTRODUCTION

2.1 BACKGROUND

The DoD must constantly balance its military mission and its commitment to stewardship on millions of acres of ranges and training lands. The military mission requires that vegetation, primarily grasses, be as resilient to military training activities as possible to maintain realism and control soil erosion.

The military faces increasingly difficult land management challenges as weapons technology improves and training and testing needs change. Complicating this challenge is the impact of continuing development, especially urbanization, outside the boundaries of military installations. As populations grow and urban expansion continues, landscapes around facilities will be further degraded, and additional pressures are likely to be brought to bear on native species, biological communities, and the ecological processes that sustain them. This growing pressure may intensify demands that federal land managers take on even greater responsibilities for biodiversity conservation (Keystone Center, 1996).

When indigenous species are lost, undesirable or invasive annual species often grow into those areas. Invasive annual plants are a problem on military lands because (1) they can reduce training realism; (2) they do not retard soil erosion as well as do perennial native species because they leave the land barren during the winter months; (3) operations to detect and control them use valuable mission resources; and (4) they can take over and destroy the habitat for desirable or threatened and endangered species. The prevalent method for controlling invasive plants on military lands is the use of herbicide applications, but these were reduced beginning in 2001. Research on pest or animal control of invasive plants is currently active in many public weed-control programs, but there is limited knowledge of the interrelationships of invasive and desirable plant species. To compete with the annual invasive or noxious weeds, sown species should germinate readily and have rapid growth rates soon after germination.

Our goals have been both to develop plants more resilient to military training activities and to get native plants to establish more rapidly to return the land more quickly to military use. Through our SERDP project "Identify Resilient Plant Characteristics and Develop a Wear-Resistant Plant Cultivar for Use on Military Training Lands" (SI-1103), we bred native and introduced grass and forb germplasms with improved establishment and seedling vigor. We also developed seeding methods to further enhance the ability of our modified germplasms to establish viable native plant stands as rapidly as possible. Our modified germplasms may be used over a broad area of the Intermountain West Region of the United States, and our seeding methods have proven successful on eastern and western ranges (Fort Drum, NY; YTC, WA; and Fort Carson, CO). During the SERDP project (Palazzo et al., 2003), we began some large-scale demonstrations and held a workshop for federal, state, and regional land managers as well as representatives of seed companies (Hardy and Palazzo, 2002). The goals of this ESTCP project were to further demonstrate and validate the germplasms and our seeding methods and to make the modified seeds available to land managers.

Before our efforts, there was little or no research on the genetics or wear-resiliency of low-maintenance rangeland plants. In our plant-breeding research, we were able to improve traits related to establishment and resiliency to training activities in introduced and native species of

rangeland grass plants, as compared to existing commercially available cultivars. We recognized, however, that even with their improved establishment rates, our new germplasms would not always be able to compete with the very aggressive establishment of annual invasive plants. To find better ways to establish native plants, we developed the concept of "ecological bridges." In this innovative work, we investigated root growth and establishment relationships among various species and, from this knowledge, selected seed mixes of rapidly establishing introduced grasses and desired native grasses. The species of introduced grasses selected varied with climatic and land-use conditions, but the primary criterion was for this plant to be relatively short-lived so that a native vegetative stand is developed. When properly selected, the introduced grasses will quickly protect the soil and create an environment in which the native grasses would gradually establish and dominate the seeded stand (Waldron et al., 2005). We also addressed the potential invasiveness of the germplasms we were developing by convening an independent review panel at YTC in 1999 to evaluate the species, especially the introduced ones, we were using in the breeding studies. The panel concluded that the plants were not encroaching into other plant communities and were not establishing monocultures (Palazzo et al., 1999).

2.2 OBJECTIVES OF THE DEMONSTRATION

In our earlier SERDP project (SI-1103), we bred native and introduced plants more resilient to military training activities and we developed seeding methods to further enhance the ability of our modified germplasms to establish viable native plant stands as rapidly as possible. Our objective in this ESTCP project was to bring the new germplasms and modified seeding methods to widespread use on DoD and other federal lands by demonstrating and further validating the new plant materials and seeding methodologies, investigating the release of cultivars, initiating seed contracts, and developing a planting guide for military facilities in the Intermountain West (Palazzo et al., 2009). All of these objectives were met.

2.3 REGULATORY DRIVERS

To be effective, the training mission must provide the resources to the military so that they can meet their mission effectively. Military lands must be maintained in settings that provide the opportunity to practice individual and battle-focused tasks and missions in realistic and challenging conditions. Throughout the DoD, land stewardship and management of its natural resources fall under the Sikes Act of 1960 (http://www.fws.gov/laws/lawsdigest/SIKES.HTML), which promotes "effective planning, development, maintenance, and coordination of wildlife, fish, and game conservation and rehabilitation in military reservations on military lands." In Army Regulation AR200-1,[1] the Army military land stewardship integrates natural resources management objectives with land warfare training requirements. Environmental Compliance requirements that address these issues include: 2.1.b "…Range and Road Maintenance" and 2.5.e "Sustainable Army Live-Fire Range Design and Maintenance." The management of lands is funded and prioritized through the Integrated Natural Resources Management Plans (INRMP) process used at every military facility.

[1] Army Regulation 200–1. Environmental Quality, Environmental Protection and Enhancement. Headquarters, Department of the Army, Washington, D.C. 13 December 2007. http://www.apd.army.mil/pdffiles/r200_1.pdf.

Our research objectives addressed these adversities by developing plant materials and seeding methods to help installations be good stewards of land resources while supporting the Sikes Act and its provisions for no net loss of training land.

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3.0 TECHNOLOGY DESCRIPTION

3.1 TECHNOLOGY/METHODOLOGY OVERVIEW

Prior to this demonstration, we conducted basic and applied research to develop the methodology. We researched modified plant materials as well as methods of establishing and maintaining native plant stands on military lands through two consecutive Corps of Engineers basic research projects on determining the genetic diversity of native plants, a SERDP project (SI-1103) on breeding the new germplasms, and leveraged funding from the U.S. Army Forces Command (FORSCOM), Army Environmental Command (AEC), and the Wyoming National Guard Bureau to implement our evaluations. With this funding, we made significant advances in using molecular markers to identify species and genetic diversity within species (Liu et al., 1997; Larson et al., 1999, 2000, 2001, 2003, 2006; Hu et al., 2000, 2001, 2005). For genetic diversity, we now have the tools to assess the genetic differences and similarities in commercial and natural seed sources. These studies provided us with background knowledge of the state of genetic diversity and plant characteristics of native plants existing on military training lands. A natural extension of this earlier research was our desire to use that knowledge as a baseline to modify plant materials to improve low-maintenance, training-resilient, native vegetation on military lands without causing significant changes in genetic diversity on the lands.

3.1.1 Plant Breeding

We used traditional plant-breeding practices to develop improved germplasms (Figure 1). We surveyed representative DoD installations to identify the most promising species along with the characteristics associated with resiliency to training activities in those species. We collected native plants with the desired traits from training lands and other conservation lands, and we used the best lines of introduced species already assembled in nurseries at USDA-Agricultural Research Service (ARS) and Pennsylvania State University. From nurseries and seeded evaluation trials from 1995 through 1998, we selected the most promising species to carry forward in the breeding program. In our program, breeding populations were typically subjected to two cycles of selection for traits such as stand-establishment vigor, rate of tillering and rhizome development, vegetative vigor, and seed-yield potential.

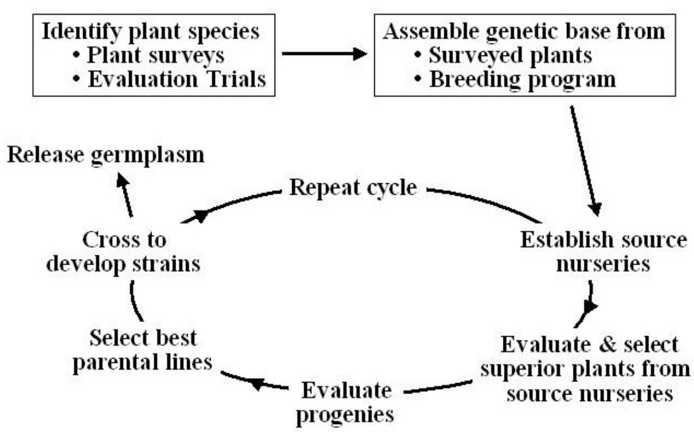

Figure 1. Plant-breeding cycle.

Although the main emphasis of the breeding program was on improving native species, introduced species were included early in the program. To ensure that the introduced germplasms we developed would not dominate lands currently inhabited by native species or prevent the return of native plants in the future, we convened an Independent Review Panel in May 1999 to evaluate the introduced species we were using in the breeding program. After evaluating 4- to 19-year-old plots at YTC that had been seeded with the standard commercial cultivars of that time, the panel found that the species we were using were not encroaching into other plant communities and were not establishing monocultures (Palazzo et al., 1999). Although these plantings were too early to have been included our modified germplasms, the panel found that the introduced species were filling in gaps but not spreading and pushing out native species, and thus were good candidates for our program.

During the breeding process, candidate populations were tested at YTC, at Fort Carson, and at breeding nurseries in UT. Our final SERDP report (Palazzo et al., 2003) describes all the evaluations performed during breeding and plant development. Related trials of many of the species improved in the breeding program are described by Asay et al. (2001) and Jensen et al. (2000).

We made four releases before the ESTCP project began (Asay et al., 1997, 1999; Jensen et al., 1998; Jones et al., 2002) and six more through the duration of the ESTCP project (Jensen et al., 2006, 2007, 2009; Waldron et al., 2006a, 2006b; Waldron et al., in press). One additional release, a possible cultivar, is expected in the next year or two. Table 1 lists the current status and significant traits of each improved germplasm.

Table 1. Improved traits and current status of SERDP-select germplasms.
(Bold indicates released germplasms.)

Introduced Selections	Original Traits	Traits of Improved Populations	Release Date
Russian wildrye			
RWR-Tetra-1	Poor seedling vigor	Selected for improved seed germination and seedling vigor, increased plant height, longer and wider leaves, increased seedling emergence, heavier seeds, improved water-use efficiency	Jones et al., 1998 (source-identified)
Syn A		Improved seed germination; part of parent population to develop Bozoisky-II	Not released
“Bozoisky-II”		Selected for improved seed germination and seedling vigor	Jensen et al., 2006 (cultivar)
Crested wheatgrass			
“CD-II”	Moderate growth in cool temperatures	Selected for increased growth under cold temperatures, drought resistance, easy establishment	Asay et al., 1997 (cultivar)
“RoadCrest”	Few rhizomes	Selected for low-maintenance turf with moderate rhizome development; suitable for gunnery ranges and roadside plantings; early spring growth	Asay et al., 1999 (cultivar)
Siberian wheatgrass “Vavilov II”	Moderate seedling vigor	Selected for seedling vigor, plant color, vegetative vigor, seed yield, drought tolerance, early spring green-up	Jensen et al., 2009 (cultivar)
Native selections	Original traits	Traits of improved populations	Release date

Table 1. Improved traits and current status of SERDP-select germplasms (continued).
(Bold indicates released germplasms.)

Introduced Selections	Original Traits	Traits of Improved Populations	Release Date
Bluebunch wheatgrass P-7	Hard to establish; sensitive to grazing	A broad-based, multiline population with no selection pressure applied	Jones et al., 2002 (selected-class)
Western wheatgrass "Recovery"	Strongly rhizomatous	Selected for plant and seedling vigor, increased germination, seed yield	Waldron et al., in press (cultivar)
Snake River wheatgrass	Seedling vigor	Selected for increased seedling vigor and seed yield	2011 (potential cultivar)
Slender wheatgrass			
"FirstStrike"	Poor persistence	Broad-based bunch-type population selected for emergence from a deep planting depth; improved plant vigor	Jensen et al., 2007 (cultivar)
Rhizomatous population	Persistent	Selected for same as above plus rhizome development	Dropped
Basin wildrye	Poor seedling vigor	Selected for improved seed germination and seedling vigor, increased plant height, longer and wider leaves, increased seedling emergence, heavier seeds, improved water-use efficiency	Dropped
Sandberg bluegrass Reliable	Early establishment after a disturbance	A broad-based, multiline population with no selection pressure applied	Waldron et al., 2006a (selected-class)
Western yarrow (a forb) Yakima		A broad-based, multiline population with no selection pressure applied	Waldron et al., 2006b (source-identified class)

3.1.2 Ecological Bridge Seeding Method

As part of our SERDP breeding project, we studied the use of noninvasive introduced grasses as an "ecological bridge" to the establishment of native grasses (Palazzo et al., 2003, Waldron et al., 2005) at YTC, Fort Drum, and Fort Carson. We have promoted the concept at professional meetings and workshops with other federal and state agencies (Cary et al., 2001; Hardy and Palazzo, 2002; Palazzo et al., 2001, 2002, 2006, 2007; Loffredo et al., 2007). The concept has been well received and has gained interest with researchers and land managers. The seeding mixtures we tested at Fort Drum, are now the standard for ranges at that facility (Palazzo et al., 1996, 2006, 2007; Hardy and Palazzo, 2002). The basic concept in the use of ecological bridge seedings is to select a geographically and climatically appropriate seed mixture of desired natives plus one or more rapidly establishing introduced species that are not persistent. The introduced species provide an early protective vegetative cover to allow the natives to establish and eventually dominate the stand (Figure 2).

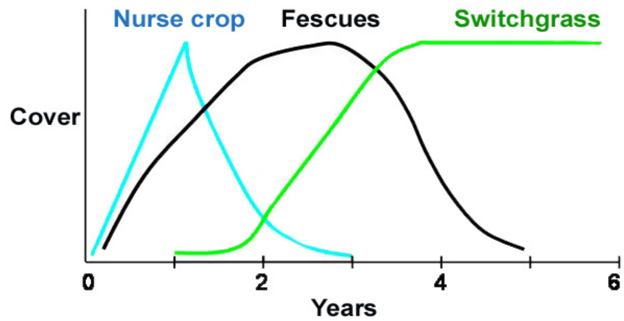

Figure 2. A conceptual model on how an introduced nurse-crop species acts as an "ecological bridge" on sandy soils at Fort Drum, allowing fescues and eventually the desired native grass, SG, to become established.

The ecological-bridge concept was tested at YTC, Fort Carson, and Fort Drum. At YTC, we tested the hypothesis that introduced Siberian wheatgrass could act as an ecological bridge to the establishment of the native bluebunch wheatgrass in a cheatgrass-infested area. The study was seeded on disturbed sites at YTC in November 1998. We used Snake River wheatgrass (native), bluebunch wheatgrass (native), and Vavilov Siberian wheatgrass (introduced) planted in monocultures of each grass, planted in binary seed mixtures of Vavilov with each native grass, and planted in alternating rows of Vavilov with each native grass. Plots with Vavilov had lower amounts of cheatgrass. Significant reductions in cheatgrass occurred when Vavilov was planted in alternating rows with bluebunch or Snake River wheatgrass as compared with each of those natives planted without Vavilov. In the Vavilov and bluebunch combinations, Vavilov allowed bluebunch to get established (Palazzo et al., 2003).

In a second study, we evaluated mixtures of native and introduced grasses in plantings at Turkey Creek, Fort Carson (Waldron et al., 2005). This study was dormant-seeded in the fall of 1997. The treatments involved a core native-grass mix plus one of five additional introduced grasses. For comparison, the Fort Carson standard mix was also seeded at increased rates to match the above treatments. The plots were evaluated in 1999, 2000, and 2001 for species composition, percent ground cover, percent annual and biennial weeds, percent introduced grasses, and percent natives. After 3 years, all mixes resulted in stands with less than 5% weeds, but there was variation in how quickly weeds were suppressed and in how predominant the native species were in the stands after 3 years (Figures 3 and 4). The mixes with crested or Siberian wheatgrasses as the introduced species had the fewest weeds in all 3 years but resulted in the lowest establishment of natives. The mixtures with a Russian wildrye as the introduced grass had at least 60% natives from the first year on and resulted in the most diverse stands of natives, but the weeds were stronger in the first 2 years. The Fort Carson mix resulted in the greatest number of natives after 3 years, but the natives established more slowly, from about 30% to 90% over the 3 years, and the mix produced much less diversity among the natives species (Palazzo et al., 2003; Waldron et al., 2005). These results suggest that there are several options, depending upon whether the main objective is rapid weed control on an area of frequent disturbance or the establishment of a diverse native stand in an area with fewer disturbances.

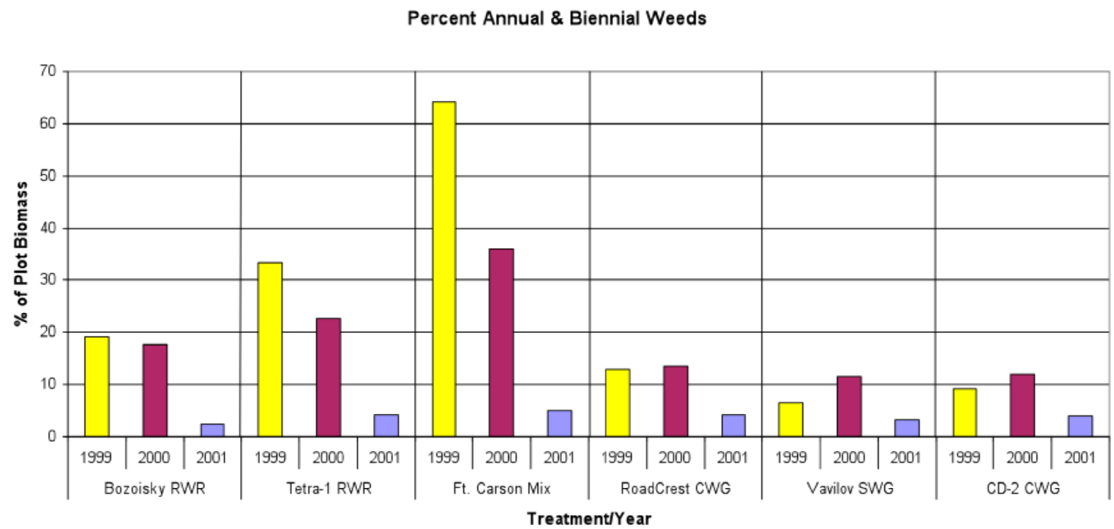

Figure 3. Percent annual and biennial weeds in Turkey Creek plots planted with the standard Fort Carson mix or with a core native mix plus an introduced grass (as named on the treatment axis).

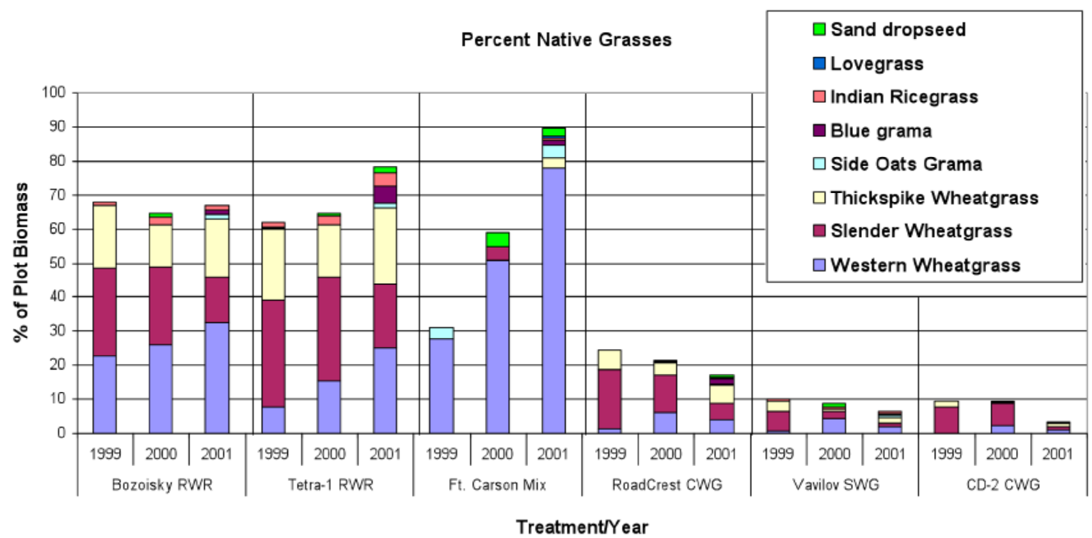

Figure 4. Percent native grasses in Turkey Creek plots planted with the standard Fort Carson mix or with a core native mix plus an introduced grass (as named on the treatment axis).

On difficult-to-revegetate sandy soils at Fort Drum, we planted mixed seedings of WL and fine fescues (FF) with the desired native SG. For treatments, we applied liquid cow manure at rates of 0, 22,400, 44,800, and 89,600 kilograms per hectare (kg/ha) (0, 10, 20, and 40 tons per acre [tons/A]), and we varied the application rate of WL at 1.12, 3.36, and 5.6 kg/ha (1, 3, and 5 lb/A). The manure slurry provided a mulching effect that prevented drying of the newly established plants, allowing time for them to develop roots long enough to reach into the deeper

soil layers. All grass species appeared to grow better where the cow manure was applied, and good soil cover was obtained over the entire area in the initial season through the strong growth of WL. The WL established quickly at all three rates sown, providing rapid control of wind and water erosion and allowing the land to be opened for training in about 1 year. The seeding provided a vegetative cover of greater than 85% in the first year with the manure applications, quickly protecting the soil and moisture. Establishment was not as good where manure was not applied, but it eventually established a good cover in the first year. As a warm-climate annual, a majority of the lovegrass died back after the first or second year, allowing the fescues to come in. After 4 years, SG dominated the stand (as illustrated in Figure 2) (Palazzo et al., 2003).

3.1.3 ESTCP Work and Continued Applications

In spring 2002, we held a 2-day workshop at Fort Carson and the Air Force Academy (Hardy and Palazzo, 2002) to introduce land managers and seed companies to the improved germplasms and mixed seeding methods. The workshop was well received, and both users and commercial growers were interested in our new plant materials. During the ESTCP project, we continued demonstrations and evaluations; visited installations in the Intermountain West; gave presentations at many workshops and conferences, including the Integrated Training Area Management (ITAM) and the Sustainable Range Program (SRP) meetings; released four new cultivars and two pre-variety germplasms; produced seed for use on military lands and began commercial seed production for one species; and produced a Planting Guide (Palazzo et al., 2009) to aid land managers in selecting appropriate mixtures for their individual situations. Our new plant materials and seeding methods provide improved plant persistence on all military lands at a reduced environmental risk with respect to habitat loss and soil erosion. As native grass stands are established more quickly, military ranges will have decreased down times, offering reduced unit-training costs, increasing the value and use of current training areas, and enhancing DoD mission-related environmental activities.

3.2 ADVANTAGES AND LIMITATIONS OF THE TECHNOLOGY/ METHODOLOGY

With these new germplasms and seeding methods, land managers will be able to more quickly establish grass stands with improved resilience to training activities, and they will be better able to establish healthy native stands while relying less on chemical or mechanical means to control invasive plants (Palazzo et al., 2005). Ranges will therefore be less prone to erosion and be more available to training programs.

The only limitations to the technology beyond availability of the seeds, which this project has helped to overcome, are unusual drought or seasonal extremes, which would affect any plant materials. The modified germplasms have been selected to possess traits that maintain or improve upon a species' current ability to tolerate cool, dry conditions.

The "alternative" technologies that these modified seeds and methods will replace are the currently available seed sources and the current trial-and-error methods of selecting the best seed mixes.

4.0 PERFORMANCE OBJECTIVES

Our primary performance objectives in this demonstration project were to evaluate the new germplasms developed under the SERDP program and demonstrate the benefits of the ecological-bridge seeding methods that came from that same program. The evaluation portion of the program allowed us to determine the types of release suitable for the SERDP-select germplasms, to gather appropriate data for those releases, and to enhance our marketing efforts to seed producers and land managers. Table 2 summarizes our performance objectives as stated in our Demonstration Plan along with the results for each objective. Results are presented in Sections 6.6 and 7.

Table 2. Performance objectives.

Performance Objective	Metric (Expected Performance)	Data Requirements	Success Criteria	Results
Quantitative				
Improved establishment of SERDP-select germplasms compared to standard cultivars (Section 7.1)	Faster establishment rate for modified germplasms compared to standard cultivars	Stand establishment rates for SERDP-select germplasms and equivalent standard cultivars	Will have significantly ($P<0.05$) greater stand establishment than base population cultivar after 1 year	Four cultivars—Bozoisky-II Russian wildrye, FirstStrike slender wheatgrass, Recovery western wheatgrass, and Vavilov II Siberian wheatgrass—had significantly ($P<0.05$) greater stand establishment than base population cultivar after 1 or more years.
Release new modified germplasms (Section 7.2)	Prepare and publish six germplasm releases describing new germplasms	Determine physiological characteristics of SERDP-select germplasms	Acceptance by Association of Official Seed Certifying Agencies (AOSCA) (2003) or equivalent state review board for certification within appropriate class germplasm	Four cultivars and two pre-variety germplasms have been released (Table 1).
Release new modified cultivars (Section 7.3)	Satisfy criteria for release of two or more germplasms as cultivars	Conduct evaluations to compare establishment, persistence, rhizome development, etc., differences between SERDP-select and standard cultivars	Satisfy necessary criteria for application to USDA as a plant variety protection (PVP) cultivar (actual acceptance can take 5 to 7 years after application)	Four cultivars have been released under ESTCP: Vavilov II Siberian wheatgrass, FirstStrike slender wheatgrass, Recovery western wheatgrass, and Bozoisky II Russian wildrye. We have the potential for one more cultivar release (Table 1).
Improved resilience of grasses to military traffic (Section 7.4)	Increased resiliency of new germplasms to military traffic compared to varieties currently in use	1. Conduct tracking experiments on established stands 2. Evaluate plant stands after one year	Significantly ($P<0.05$) better stands in new germplasms 1 year after tracking as compared to standard varieties	Three new cultivars—Bozoisky II Russian wildrye, Vavilov II Siberian wheatgrass, and SERDP-select Snake River wheatgrass—did significantly better than the commonly available varieties for all treatments.

Table 2. Performance objectives (continued).

Performance Objective	Metric (Expected Performance)	Data Requirements	Success Criteria	Results
Improved establishment of native grass stands (Section 7.5)	Greater establishment of natives in ecological-bridge seedings compared to standard mixes	Evaluate mixed seedings on at least two different sites	Obtain a grass stand of native plants four years after planting	Accomplished at Fort Drum; all mixes at Guernsey established more rapidly and persisted better than the standard Guernsey mix (drought prevented evaluation for 4 years).
Reduce weeds in grasses on training lands (Section 7.6)	Reduced stands of noxious weeds in ecological-bridge seeding mixes compared to mixes currently in use or natives sown alone	Evaluate percentage of weeds in stands sown with ecological-bridge mixes, standard mixes, and natives sown alone	Significant ($P<0.05$) reduction of weeds in ecological-bridge stands as compared to natives sown alone after two years	No significant differences at YTC or Guernsey, although the highest percent weeds were found with the all native mix 2 and core native mix 4 at the Guernsey River site after 2 years.
Qualitative (Section 7.7)				
Reliability	Ability to withstand environmental conditions as well as or better than existing cultivars	Observations and data evaluation during demonstration	Planting in several different climatic locations	We have successfully established our modified germplasms at four facilities in two climatic areas within the 4-year time frame of this demonstration.
Ease of use	No additional personnel or equipment required	Experience during demonstrations	No increase in time or cost required for soil preparation and seeding	Most operations can be completed with a single tractor pass; no new methods or equipment are required.
Versatility	Comparable results at two or more test sites	Evaluations of plant stands at two or more sites	Observation of improved performance at multiple sites	Modified germplasms were successful on different soils and climatic areas.
Maintenance	No need to reseed, fertilize, or mow	Evaluations over 2 to 3 years after planting	Experience during demonstrations	Plants required no maintenance after seeding; plant stands continued to thrive throughout the demonstration.
Scale-up constraints	1. Availability of seed	a. Prepare breeders seed b. Contract with seed producers	Seed available from seed producers	a. Seed of three grasses was distributed to eight military facilities in the Intermountain West over 2 years. b. We have established one commercial seed contract.
	2. Awareness of seed capabilities and appropriate planting methods	a. Prepare releases b. Prepare planting guide	Publish releases and planting guide; widely distribute planting guide	a. Six new releases have been published under ESTCP. b. The Planting Guide has been published (Palazzo et al., 2009).

5.0 SITE DESCRIPTION

The criteria for selecting our locations were their importance to the military mission and the degree to which their climates represent other DoD installations. We considered test sites in two climatic areas: the Intermountain West and the Northeast for the ecological bridge studies, and in the Intermountain West for our plant development research (Figure 5). Sites in these climatic areas had a diversity of landscapes in terms of soil thickness, microclimates, and terrain to support the need for multiple germplasm species grown in mixtures. The Intermountain West test sites also contain a diversity of microclimatic areas that contain a greater diversity of plant species than a single location. We also wanted to demonstrate the germplasms and seed mixtures on military lands that could potentially be subjected to military vehicle traffic as part of the validation testing. YTC; Fort Drum; Camp Guernsey, Guernsey, WY; and Dugway Proving Ground (DPG), Dugway, UT, met these criteria, and they provided strong financial and personnel support.

The comparative field evaluations of new germplasms with existing cultivars were conducted at Camp Guernsey, YTC, and DPG, and the demonstrations of ecological-bridge seed mixtures took place at Camp Guernsey, YTC, and Fort Drum. Earlier studies on our developing germplasms and ecological-bridge mixtures were performed at Fort Carson; our work at Fort Carson provided the basis for our cost analyses.

In addition to the larger demonstration studies, we conducted further tests for cultivar validation at the ERDC-CRREL greenhouse and at several nursery-field sites. These additional locations are described in Section 6.3 (Design and Layout of Technology Components.)

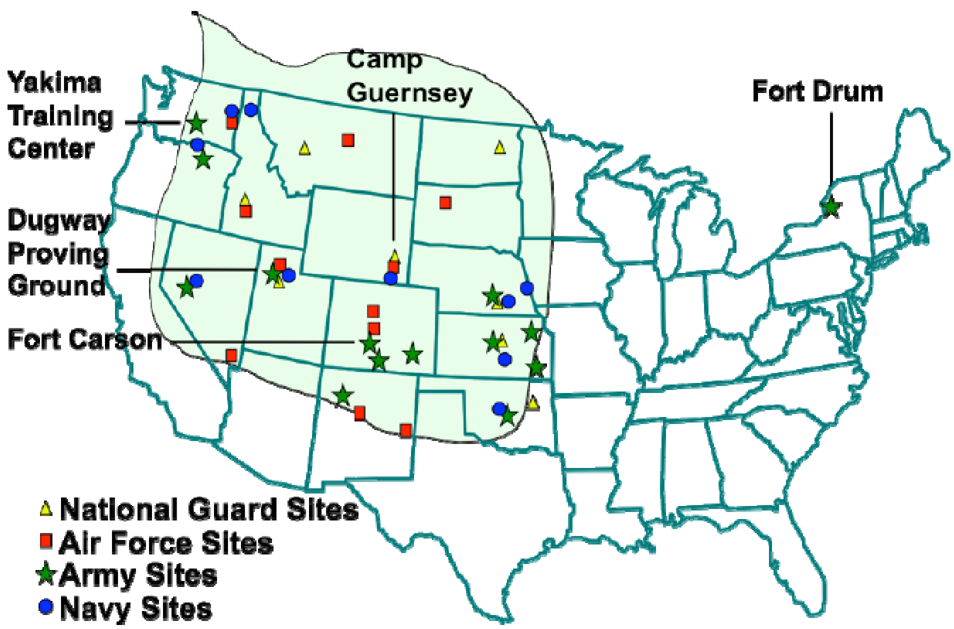

Figure 5. The general range of distribution for SERDP-select germplasms, showing locations of the main demonstration sites and other military facilities in the Intermountain West as they existed at the beginning of this study.

5.1 SITE LOCATION AND HISTORY

YTC is an Army facility in south-central Washington (Figure 5). We had done revegetation at YTC before and during our SERDP breeding program, and we used YTC for the tracked vehicle studies under the SERDP project (Palazzo et al., 2005). The area we used in this demonstration was Exit 11, which is in the northwest corner of the facility and is typically used for training with tracked or wheeled vehicles.

Camp Guernsey is a 42,180-acre Wyoming Army National Guard (WYARNG) military training area in southeastern Wyoming along the North Platte River (Figure 5). Camp Guernsey is the primary training area for WYARNG, with heaviest use occurring during the summer months. Training exercises conducted at Camp Guernsey include firing small arms (individual and crew-served weapons), artillery, and mortar; tactical and administrative bivouacs; engineer training; and bridging and river-crossing operations. Emphasis is on training field artillery units; however, training facilities and ranges are available for infantry, engineer, aviation, maintenance, and medical units. Other common training exercises conducted at Camp Guernsey include map exercises, tactical exercises without troops, command post exercises, situational training, field training, live fire, and lanes training. We used two sites: the River site, southeast of the cantonment adjacent to the North Platte River, and the Tower site, north of the cantonment near the radar tower. These two sites are primarily used for training with tracked and wheeled vehicles.

DPG is located in the Great Salt Lake Desert, approximately 85 miles southwest of Salt Lake City, UT, within the eastern Great Basin, specifically the Bonneville Basin (Figure 5). DoD has designated the 398,542-ha (798,855-acre) DPG as a Major Range Test Facility Base (MRTFB) and the primary chemical and biological defense testing center under the Reliance Program. Testers here determine the reliability and survivability of all types of military equipment in chemical or biological environments. The primary mission of DPG is to plan, conduct, analyze, and report the results of exploratory, developmental, and production tests of chemical and biological defense systems, smoke and obscurant illumination material and delivery systems. The demonstration site was located at the highest elevation of the eastern part of the facility.

Fort Drum is located just east of Lake Ontario in upstate New York (Figure 5) and is under the command of the U.S. Army Commands (ACOM), formerly FORSCOM. The primary mission of the Fort Drum garrison is to provide facilities and services to U.S. Armed Forces that require land and airspace to practice combat skills and operations year-round. Fort Drum is also home to the 10th Mountain Division (Light Infantry) whose mission is to deploy rapidly anywhere in the world and be prepared to fight and win upon arrival. The 10th Mountain Division Light Infantry consists of light infantry brigades, an aviation brigade, a division artillery brigade, a division support command brigade, an engineer battalion, a signal battalion, an intelligence battalion, an air defense battalion, a military police battalion (provisional), a division band, and a headquarters company. At Fort Drum, we used two study sites in the western part of the facility: training Area 8, about 5 miles north of the cantonment, and the Airport site, adjacent to the cantonment. The Airport site is a restricted area not used for training; Area 8 has been used for defilades (deep trenches).

Fort Carson is an ACOM facility in south-central Colorado south of Colorado Springs at 1920 m elevation (Figure 5). The military mission of Fort Carson is to train, mobilize, deploy, and

sustain combat-ready, multicomponent integrated forces. Fort Carson provides facilities and service to U.S. Armed Forces that require land and airspace to practice combat skills and operations on a year-round basis. In our SERDP breeding program, we used the Turkey Creek area near the northwest corner of the facility (38° 37' 20" N, 104° 52' 40" W). Our fenced study site was tilled to a depth of 20 cm to imitate disturbance and reduce existing weeds in spring of 1997. Areas near the study site are regularly seeded with the military seed mix after disturbance by tracked vehicles during training exercises. We compared data from this study along with existing costs at Fort Carson to develop our cost savings information (see Section 8).

5.2 SITE CHARACTERISTICS

YTC encompasses an area over 130,000 ha (321,237 acres) in the Columbia basin of south-central Washington. The YTC region is part of the shrub-steppe, the largest of the grassland regions in North America (Rogers and Rickard 1998). YTC soils are typically loess overlying basalt, and the climate is characterized as semiarid, temperate, and continental with cold, wet winters and hot, dry summers (Jones and Bagley 1997). The region receives less than 25 cm (10 inches) of average annual precipitation. However, altitude plays a major role in site-specific annual precipitation. YTC sites at about 455 m (1500 ft) altitude receive about 20.3 cm (8 inches), while sites near 910 m (3000 ft) altitude have lower temperatures and receive 30.5 cm (12 inches).

The YTC soils and vegetation are typical for central Washington state: shrub-steppe consisting of deep silty clay-loam soils (Drysel, Meloza-Roza; fine, montmorillonitic, mesic Xeric Camborthids) on a 0–3% slope, and dominated by big sagebrush (Artemisia tridentata) (Daubenmire, 1970; Jones and Bagley, 1997). The dominant vegetation is perennial bunchgrass such as bluebunch wheatgrass (Elytrigia spicata) or Poa secunda.

The climate at Camp Guernsey is considered semiarid with a total annual precipitation of 33-35 cm (13 inches) Peak precipitation occurs during May and June. Average daily temperatures range from –1°C in the winter to 21°C in the summer. The soils can be broken up into three areas: cantonment, north training area, and south training area. Soils in the south training area are shallow to moderately deep loamy and sandy soils with many areas of rock outcrops; slopes are moderately steep to steep. In the north training area, soils are deep to moderately deep silty and loamy soils found on gentle to moderately steep rolling hills (Warren et al., 2000). Our two sites are high plains, moderate relief rangeland. The River site is in the south training area near the North Platte River (N 42° 15.001' W 104° 44.090'; elevation 1320 m [4330 ft]) and has very dry sandy soil. The Tower site is in the north training area near the Guernsey Radar Tower (N 42° 14.385' W 104° 44.302'; elevation 1393 m [4570 feet]) and has silty soil. These two sites are representative of the warm- and cool-season grass transition zone where western wheatgrass is often a dominant species.

Surrounded on three sides by mountain ranges, the DPG’s terrain varies from level salt flats to scattered sand dunes and rugged mountains. DPG is in the Great Salt Lake Basin where there is a great variability in precipitation patterns. On average the area receives 19 cm (7.5 inches) of annual precipitation, but the lowest and highest amounts were 8.5 cm (3.32 inches) in 1966 and 38 cm (14.99 inches) in 1982. The average daily temperatures range from –2.5°C in winter to 24.3°C in summer, but it can reach 40°C. The aridity of the area is caused by the rain shadows cast by the High Sierra Mountains of California and Nevada, and to a lesser extent by the Deep

Creek, Pilot, and Snake Ranges of western Utah and eastern Nevada. The demonstration site was north of English Village where the soils are a fine sand, with 2–15% slopes. The main topographic features of DPG area are rugged fault block mountains, generally running from north to south, with fairly level intervening valleys. The Cedar Mountains, which are an example of this type of mountain range, form the northeastern boundary of the installation, terminating just north of English Village. The peak elevation of the Cedar Mountains is 2340 m (7,700 feet), which is outside of the DPG boundary.

Fort Drum encompasses two major physiographic provinces, the Lake Erie-Ontario Lowlands and the Adirondack Uplands. The southwestern two-thirds of the installation, where the Airport and Area 8 sites are located, are part of the Lake Erie-Ontario Lowlands division. In this area, surface geological features are recessional moraines, small sand plains, drumlins, swamps, and drainage patterns resulting from Pleistocene glaciation. The geology at Fort Drum is underlain by a variety of metamorphic, igneous, and sedimentary bedrock ranging from Precambrian to Middle Ordovician. The oldest metamorphic rocks belong to the Grenville Complex and consist mainly of metamorphosed Precambrian quartzite, gneiss, schist, and marble. These rocks stretch in a wide northeast-southwest band across Fort Drum and border the igneous Adirondack massif and associated foothills to the east.

Fort Drum soils are generally developed from deltaic/lacustrine or glacial deposits. The soils vary from sandy gravels to loams to clays to mucks. Soils in the region are generally shallow and poorly drained; soil permeability is slow to moderate. The two study sites at Fort Drum are located on a Plainfield sandy soil and contained a mean of 92% sand, with small amounts of silt and clay. Both sites are on relatively level open areas with less than 25% tree canopy, and the areas were windblown and mostly devoid of vegetation at the beginning of the study. Grasslands and meadows on sandy soils at Fort Drum are dominated by common HG, stiff-leaved aster, poverty oat grass, and the sedge Carex lucorum. Grasslands on sandy soils are visually distinct from corresponding communities on less sandy soils, showing a relatively species-poor vegetative diversity with a predominance of native species.

Fort Drum has a primarily humid, continental climate with relatively long, cold winters and short, warm and often humid summers. The mean annual temperature at Fort Drum, averaged over the past 10 years, is 8.9°C (48°F). January is the coldest month, closely followed by February and December. Temperatures fall below –18°C (0°F) on about 20 days during these 3 months; below-freezing temperatures occur on about 104 days from December to March.

The Fort Carson research site at the Turkey Creek Recreation Area has soils that are a fine sandy loam (mixed, calcareous mesic Ustic Torriorhents). The 22-year mean annual precipitation for Colorado Springs is 38.3 cm, with approximately 80% of this precipitation received from April to September. This site contains vegetation typical of the Great Plains steppe provinces (Bailey, 1995). Shrubs are rare, but one-seed juniper (Juniperus monosperma [Engelm.] Sarg.) has encroached into grasslands during the last century. Dominant grass species include western wheatgrass, blue grama (Bouteloua gracilis [H.B.K.] Lag. ex Steudel), and sideoats grama (B. curtipendula [Michx.] Torr.). Subdominant grasses include green needlegrass [Nassella viridula (Trin.) Barkworth] and needle and thread grass (Stipa comata Trim & Rupr.).

6.0 TEST DESIGN

6.1 CONCEPTUAL TEST DESIGN

Demonstration activities included: (1) comparative field evaluations of new germplasms with existing cultivars, (2) evaluations of ecological-bridge mixes versus standard mixes, (3) traffic tests on established plots, and (4) germination and nursery-field studies to further validate cultivars for release.

The comparative field evaluations of new germplasms with existing cultivars were conducted at Camp Guernsey, YTC, and DPG, and the demonstrations of ecological-bridge seed mixtures took place at Camp Guernsey, YTC, and Fort Drum. Traffic studies on germplasms and mixes were conducted at YTC. Additional studies to validate germplasms for release were conducted at the ERDC-CRREL greenhouse and several USDA-ARS nursery-field sites.

At least six SERDP-select germplasms were tested at Guernsey, Yakima, and Dugway, along with a corresponding existing cultivar for each; the exact number of germplasms varied at each site, depending on seed availability and appropriateness to climate and soil conditions. In addition, two seed mixes were tested at one location at YTC, and seven mixes were tested at two locations at Camp Guernsey. At Fort Drum, eight mixes were tested in two locations. Plots at all sites were monitored yearly and measured for stand establishment or percent of sown species, other plant species, weeds, and bare ground. Details of plantings and monitoring schedules are provided in the following sections.

6.2 BASELINE CHARACTERIZATION AND PREPARATION

The demonstration seeding sites at YTC and Camp Guernsey were in areas previously used for training. They were prepared by rototilling in the spring before planting, followed by summer applications of Roundup® for nonselective removal of existing vegetation and Trimec® (2,4-dichlorophenoxyacetic acid [2,4-D]) for control of broad-leaf weeds; YTC sites received one spraying of the chemicals and Guernsey sites received three. Seeds were planted that fall at YTC (2002) and the following spring at Guernsey (2004 for the River site and 2005 for the Tower site) using a cone seeder equipped with double-disk furrow openers and depth band regulators (also called a no-till seeder).

At DPG we used disturbed bare land, so no preparation other than rototilling was needed. The site was rototilled in the summer of 2005 and seeded that fall.

At Fort Drum, both research sites were relatively level and the areas were wind blown and devoid of vegetation at the beginning of each study in May 2002. We first broadcast an application of 10-10-10 grade fertilizer at a rate of need 0.72 tonnes per hectare (t/ha) (650 pounds per acre [lbs/A]). We next applied dolomitic limestone by broadcast at a rate of 2,000 lbs/A (need 0.91 t/ha). After application of soil amendments, the sites were divided into the respective study plots, and the seeds were sown with a Great Plains no-till seeder. The Area 8 site has previously been used for defilade training (trenches); the Airport site is in a restricted area not used for training.

No mobilization or installation was required at any facility other than travel of research personnel to the sites. There was no special equipment to be maintained, nor were there any hazardous wastes involved.

6.3 DESIGN AND LAYOUT OF TECHNOLOGY COMPONENTS

As noted above, demonstration activities included (1) comparative field evaluations of new germplasms with existing cultivars, (2) evaluations of ecological-bridge mixes versus standard mixes, (3) traffic tests on established plots, and (4) germination and nursery-field studies to further validate germplasms for release. These evaluations allowed us to confirm the types of releases suitable for the SERDP-select germplasms, gather appropriate data for those releases, and enhance our marketing efforts to seed producers and land managers.

Except as noted below, the demonstrations were similar at the selected sites. The setup details for each activity are given below.

6.3.1 Field Evaluations of New Germplasms: Comparisons of Germplasms with Existing Cultivars (Monocultures)—Design

We seeded the monoculture evaluation plots at YTC, Camp Guernsey, and DPG to provide the required testing for release of any new cultivars and to demonstrate the superiority, if any, of the new germplasms compared to currently available cultivars. These studies provided data and a showcase for our marketing efforts and allowed us to determine which SERDP-select germplasms would meet certification requirements for cultivars.

The Exit 11 site at YTC was seeded October 21-22, 2002. A second site (the River site) was seeded in spring 2004 at Camp Guernsey, and a third site (the Tower site) was seeded at Guernsey in spring 2005. A site was seeded at Dugway in fall 2005.

The trials were planted with a cone seeder equipped with double-disk furrow openers and depth band regulators. This seeder allows the comparison of entries with limited seed. The plants were not irrigated or fertilized; they were allowed to grow naturally in the local climate and soils. At YTC, the plots were subjected to military traffic after the plants are fully established (see military traffic section below).

The monoculture evaluations compared each of seven SERDP-select germplasms (four native and two introduced grasses plus one native forb, yarrow) with at least one standard cultivar. Additional species and varieties were planted in some locations; the lists below show only those of interest to this demonstration. The native germplasms were as follows; the name of the standard cultivar used in all trials is in parenthesis:

- Bluebunch wheatgrass, Pseudoroegneria spicata (Pursh) A. Löve (Goldar)
- Western wheatgrass, Pascopyrum smithii (Rydb.) Á. Löve (Rosana)
- Snake River wheatgrass, Elymus wawawaiensis J. Carlson & Barkworth (Secar)
- Slender wheatgrass, Elymus trachycaulus (Link) Gould ex Shinners (Pryor)
- Western yarrow, Achillea millefolium L. (commercial variety)
- Basin wildrye, Leymus cinereus (Trailhead)
- Sandberg bluegrass, Poa secunda (J. Presl), (common variety).

The introduced entries were as follows. The Syn A Russian wildrye line was developed prior to the initiation of the SERDP breeding program. Syn A was not released, but was used in the development of a subsequent cultivar, Bozoisky II, and is referred to as Bozoisky II parent in the summary tables in these sections. An additional Russian wildrye germplasm, Tetra 1 (Jensen et al., 1998), and two crested wheatgrasses, “CD-II” and “RoadCrest” (Asay et al., 1997, 1999), were released during the SERDP program and are used in many of the demonstration seedings (not listed below).

- Russian wildrye (Syn A), Psathyrostachys juncea [Fisch.] Nevski (Bozoisky-Select)
- Siberian wheatgrass, Agropyron fragile (Roth) Candargy (Vavilov).

6.3.2 Ecological-Bridge Demonstration (Mixtures)—Design

We evaluated mixtures at YTC, Camp Guernsey, and Fort Drum. Plots at YTC and Camp Guernsey were prepared and seeded with the monocultures as described above for germplasm evaluations in fall 2002 at YTC, and spring 2004 and 2005 at Guernsey (see Section 6.2 and activity 1 of this section). The two Fort Drum sites were prepared as described in Section 6.2 and seeded in 2002.

The same set of two mixtures was evaluated at both YTC and Guernsey (Table 3). One was an all-native mix and the second was an ecological-bridge mix containing both natives and selected introduced species. At Guernsey, an additional set of mixtures was evaluated (Table 4) with duplicate seedings at the two sites; these mixtures tested various ecological bridge combinations and compared them to the all-native mix in use at Guernsey. The mixtures were planted as entries among the monoculture seedings at YTC and Guernsey

Table 3. Seed mixtures planted at both YTC (Exit 11 sown in October 2002) and Camp Guernsey (River site, March 2004, and Tower site, March 2005).

Mix 1: Introduced/native	Seeding rate (lb/acre)	Mix 2: All native	Seeding rate (lb/acre)
Western wheatgrass (SERDP)	4	Bluebunch wheatgrass (Goldar)	5
Russian wildrye (Bozoisky) (I)	3	Snake River wheatgrass (SERDP)	5
Siberian wheatgrass (SERDP) (I)	3	Western wheatgrass (SERDP)	5
Bluebunch wheatgrass (Goldar)	3	Western yarrow (SERDP)	0.1
Snake River wheatgrass (SERDP)	3	Sandberg bluegrass (common variety)	0.3
Western yarrow (SERDP)	0.1		
Forage kochia (I)	0.5		
Sandberg bluegrass (common variety)	0.3		

Table 4. Additional mixtures sown at Camp Guernsey in March 2004 (River site) and March 2005 (Tower site).

Mix	Native	% Seeds/ plot*	Introduced	% Seeds/ plot	Purpose/change
3. Current Guernsey mix	Little bluestem (Camper) Bluegramma (Lovington) Buffalograss (Texoka) Western wheatgrass (Rodan) Thickspike wheatgrass (Critana)	18 59 4 8 11	None		Current Guernsey mix for comparison with our proposed changes (4-7)
4. Test control	Bluegramma (Lovington) Western wheatgrass (SERDP TC2) Thickspike wheatgrasses (Critana) Slender wheatgrass (SERDP) Buffalograss (Texoka)	24 24 24 24 4	None		Our suggested all-native control
5. Test mix	Same natives as #4	#4 adjusted proportionally to 21.6 and 3.6%	Intermediate wheatgrass (AI)	10	Our suggested all-native mix plus single introduced species
6. Test mix	Same natives as #4	same as #5	Siberian wheatgrass (SERDP)	10	Test different introduced
7. Test mix	Same natives as #4	same as #5	Russian wildrye (SERDP Syn-A)	10	Test different introduced

*% seeds/plot = percent pure live seeds (PLS) per plot, which is based on numbers of seeds, not seed weight
In spring 2004, 3600 seeds were planted in each 18-m^2 (100-ft^2) plot.

At Fort Drum we further evaluated the ecological-bridge concept with species adapted to the northeastern United States; we didn't test any of our modified cultivars. The Airport and Area 8 sites were sown in May 2002 to evaluate different seeding mixtures of the three ecological-bridge seed components. The research design was a two-way factorial; at least four to five samples were taken in each plot at each sampling time. No liquid cow manure was applied. Seeds were sown with a no-till seeder. The mixtures sown at each site are shown in Table 5. We varied the mixtures a bit from our earlier Fort Drum studies (see Section 3.1). While SG is often desirable as a native, it grows tall and can carry fire, so we also tested native HGs along with the shorter growing introduced fescues. We were still using the annual WL as the nurse crop when these sites were seeded, although we have since dropped it as it could be considered invasive in some locations because it does not completely die out over the winter months. The FF were a blend of Azay sheep fescue and Scaldis and Osprey hard fescue, and the HGs were a blend of Norcoast bearing HG, Nortran tufted HG, and a common variety of tufted HG. The perennial grasses were sown in a mixture; the annual WL was sown separately.

Table 5. Mixtures seeded at two Fort Drum sites (May 22, 2002).

Mixture	Species	Seeding rate (lb per Acre)
1	WL	2
2	WL HG	2 38
3	WLs SG	2 38
4	WL HG SG	2 38 24
5	WL HG SG3 FF	2 13 12 12
6	WL HG FF	2 13 24
7	WL SG FF	2 18 18
8	WL FF	2 38

6.3.3 Military Traffic on Monocultures at Yakima Training Center—Design

The objective of this evaluation was to compare the resiliency to military traffic of the SERDP-select germplasms that we developed with named cultivars that are currently on the market. Demonstration plots that were planted at YTC in October 2002 were subjected to military traffic in June 2005. A planned June 2006 tracking could not be carried out because a Stryker vehicle was not available. We monitored the plots for two seasons, completing the demonstrations by the fall of 2007.

As described above, the Exit 11 plots were planted in October 2002 using a randomized complete block design with four replications and 20 species per replication. The cultivars of the species tested were the commercial variety as compared to the SERDP-select germplasm. The species tested and the named cultivars in parenthesis were: bluebunch wheatgrass (Goldar), Russian wildrye (Bozoisky-Select), Sandberg bluegrass (common), Siberian wheatgrass (Vavilov), slender wheatgrass (Pryor), Snake River wheatgrass (Secar), western wheatgrass (Rosana), Basin wildrye (Trailhead), and western yarrow (common).

The tracking operations are described in Section 6.4.

6.3.4 Cultivar Validation: Germination and Nursery-Field Studies—Design

Additional data needed to validate releases of the new germplasms were acquired through germination studies at CRREL and additional nursery-field trials. Appendix C summarizes the

various types of pre-variety and cultivar releases and the requirements to meet each level of release.

Germination studies were conducted in April 2005. The SERDP-select germplasms were evaluated against their known counterparts in the CRREL environmental chambers located in the greenhouse. Ten seeds of each of the various plants were placed in growth pouches in growth chambers to study plant root initiation differences. There were five replications of each germplasm per run, with each temperature run four times for a total of 200 seeds studied. The environmental chambers were set at temperatures of 10, 15, 20, 25, and 30°C with 12 hours of daylight. Plant root initiation for the seed was determined according to the AOSCA (2003). Pouches were examined daily for up to 28 days.

Space-planted nursery-field trials to validate our cultivars as compared to other range grass cultivars were conducted at several USDA sites to provide data for Exhibits B, C, and D for PVP as described in Appendix C. Six nursery-field trials for Bozoisky II Russian wildrye were planted in 1999 during our SERDP project as part of the Northern Plains Area Regional Trials (NPA). Between 2002 and 2005, five fall-dormant-seeded nurseries were established to compare seedling establishment and stand development of our other culitvars (Recovery western wheatgrass, FirstStrike slender wheatgrass, Vavilov II Siberian wheatgrass) and other range grass cultivars. Data from the YTC Exit 11 (fall dormant-seeded), the two Camp Guernsey sites (spring-seeded), and Dugway (fall dormant-seeded) were also included in cultivar validation. Nursery sites in addition to our demonstration sites described above included: Beaver, UT; Malta, ID; two sites in Fillmore, UT; Curlew Valley, ID; and Blue Creek, UT.

6.4 FIELD TESTING

Field testing consisted of measurements of plant stands for several years after the various monoculture germplasm and seeding mixtures were sown. After the Stryker tracking event at YTC in 2005, plots were measured for two additional years. Table 6 summarizes the activities and data taken at the various field sites. Descriptions of the activities are given in the sections below; measurement protocol is described in Section 6.5.

Table 6. Time line of field events.

	YTC Exit 11	Guernsey River site	Guernsey Tower site	Dugway	Drum Airport site	Drum Area 8
2002 – spring	rototilled				Mixes seeded (May 22)	Mixes seeded (May 22)
summer	Roundup® & Trimec® (one spraying)					
fall	Monocultures & mixes seeded (Oct 21-22)					
2003 – spring	Establishment measurements (May 14)	rototilled				

Table 6. Time line of field events (continued).

	YTC Exit 11	Guernsey River site	Guernsey Tower site	Dugway	Drum Airport site	Drum Area 8
summer		Roundup® & Trimec® (three sprayings)			1-year measurements (June 24)	1-year measurements (June 24)
fall						
2004 – spring	1-year measurements (April 19)	Monocultures & mixes seeded (March 31) Establishment measurements (June 2)	rototilling			
summer			Roundup® & Trimec® (three sprayings)		2-year measurements (June 29)	No measurements (site was used for training)
fall						
2005 – spring	2-year measurements (June 2) Stryker tracking (June 14)	1-year measurements (June 2)	Monocultures & mixes seeded (March 23) Establishment measurements (June 2)			
summer				Rototilled	3-year measurements (Sept 7)	
fall				Monocultures seeded (Nov 7)		
2006 – spring	Stand frequency one year after tracking			Establishment measurements (May 10)	4-year measurements (June 7)	
summer		2-year measurements (July 19)	1-year measurements (July 19)			
fall						
2007 - spring	Stand frequency two years after tracking		No measurements due to drought conditions	No measurements		

6.4.1 Field Evaluations of New Germplasms: Comparisons of Germplasms with Existing Cultivars (Monocultures)—Testing

Evaluations of monocultures at YTC and Guernsey consisted of measurements taken annually (spring) over a 2-year period, except at the Tower site at Guernsey where we were unable to take 2-year measurements due to drought. At DPG, we took establishment measurements but no further data as the establishment was very poor. The data collected included establishment and persistence of sown species. Establishment and persistence were recorded as percent cover as

measured by using modified Vogel frames of different sizes or by visual ratings (both protocols are described in Section 6.5). We also recorded percent bare ground, percent dead plants, and percent weeds in many instances.

6.4.2 Ecological-Bridge Demonstration (Mixtures)—Testing

The establishment of plants during the first growing season, 2 to 6 months after seeding, was measured at YTC and Camp Guernsey by taking frequency measurements of total plants. At both sites, we used a 48-grid frame of 6.35-by-6.35-cm (2.5-by-2.5-inch) squares (see Section 6.5, Sampling Protocol) for the establishment measurements. It was not possible to distinguish among the different species during the early stage of growth when mixtures are planted. Following the establishment year, we took spring or summer measurements for the next 2 years with a 24-grid frame of 12.7-by-12.7-cm (5-by-5-inch) squares at YTC and at Camp Guernsey in 2005. In 2006 at Camp Guernsey, we took visual ratings for the 2-year River site measurements and 1-year Tower site measurements; we were unable to take 2-year measurements at the Tower site due to drought conditions.

At Fort Drum, we took measurements for 4 years at the Airport site; Area 8 was used for training after the first year, so we have only 1-year measurements for that site. We measured plant cover of sown species, bare ground, and weedy species at all three facilities. The first-year measurements were taken with a 24-grid frame of 12.7-by-12.7-cm (5-by-5-inch) squares; in the remaining years, we used a 36-grid frame of 12.7-by-12.7-cm (5-by-5-inch) squares (see Section 6.5, Sampling Protocol); at least five samples were taken per plot.

6.4.3 Military Traffic on Monocultures at YTC—Testing

On June 2, 2005, we made a reconnaissance of the site to determine the condition of the species and to see if it was a good time to do the traffic experiment. The vegetation was very uneven, and several species were nearly gone. Precipitation on the plots had been sparse for some time, and the soil was very dry. Only a few plots with Vavilov and SERDP-modified Vavilov Siberian wheatgrass, SERDP western wheatgrass, and Bozoisky (Syn A) Russian wildrye were reasonably covered.

A Stryker was used to track the plot on June 14, 2005. The vehicle has a 7.4-ft track width and 15-inch tire width when loaded. Rates of tracking and the vehicle velocity required to achieve a light and a heavy treatment were determined in the field outside the plot area. These off-site tests showed that straight tracks of one and four passes per replication at a vehicle speed of 20 miles per hour produced sufficiently different rutting.

Traffic patterns were set up such that three rates of disturbance—zero passes, one pass, and four passes—would be applied per replication for a total of 12 treatments. Disturbance rates were randomly applied to each replication and perpendicular to planted entries (Figure 6).

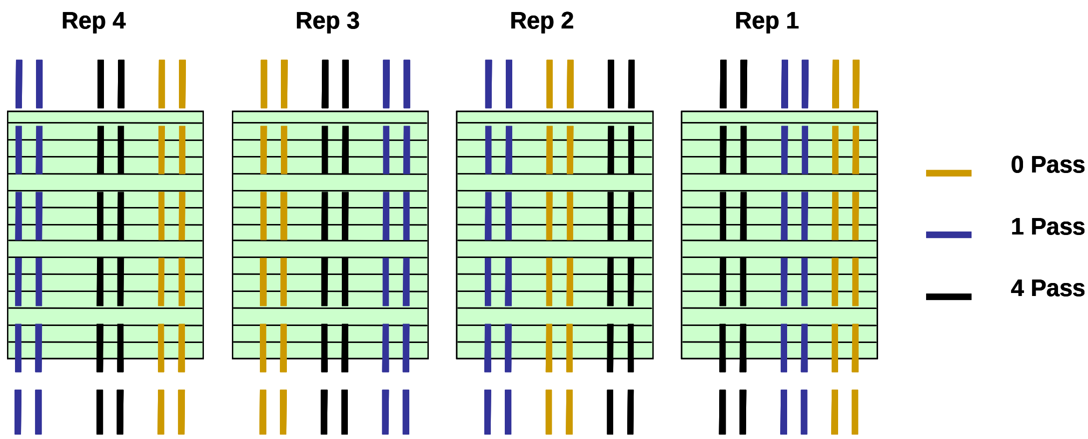

Figure 6. Traffic design at YTC Exit 11.
(Plot 1, rep 1, is in the lower right corner; plot numbers go from the bottom up)

Measurements taken before and after the traffic passes and 1 and 2 years after the event are summarized in Table 7. The locations of the measurements in relation to the ruts are shown in Figure 7. The measurement protocols are described in Section 6.5.

Table 7. Soil and vegetation measurements before and after traffic event (June 2005) on Exit 11 at YTC.

Characteristic	Protocol	Before	Immediately After	After 1 Year	After 2 Years
Soil Characterization					
Shear strength	Pilcon shear vane	X		X	X
Soil moisture	Delta T ML2x moisture probe	X		X	X
Soil bulk density	Drive-cylinder, 283-cc soil cores	X			
Soil compaction	Drop-cone penetrometer		X	X	X
Rut depth	Pin profilometer		X	X	X
Vegetation Response					
Plant resiliency	Percent cover	X	X	X	X

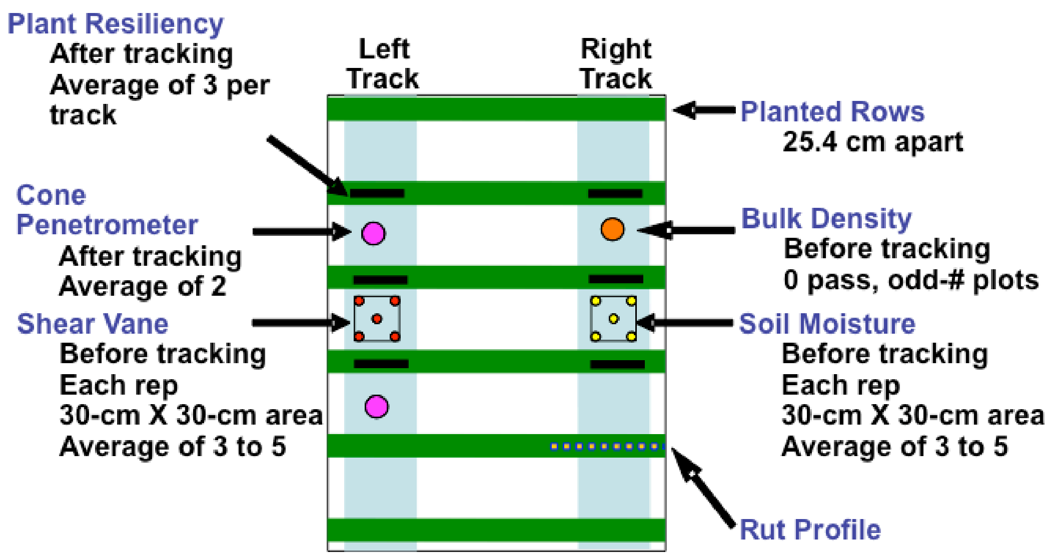

Figure 7. Location of sampling points before and after tracking. (Green represents planted rows, which are perpendicular to the tracking ruts.)

The soil-characterization measurements were made so as to fully define the soil conditions prior to tracking so the degrees of vehicle impacts from future tracking experiments could be compared to the soil conditions and correlations defined.

In 2006 and 2007 (1 and 2 years after tracking), soil physical properties (shear strength, soil moisture and compaction) were remeasured with the exception of soil bulk density. Rut profiles were also remeasured to determine changes in the profile over time.

To measure rebound of the planted species, the three center rows of each track were measured using the 12.5-by-12.5 cm (5-by-5-inch) grid to determine the percent cover. The two tracks were then averaged to determine percent cover for each species.

6.4.4 Cultivar Validation: Germination and Nursery-Field Studies—Testing

In the germination studies in the CRREL environment chambers, plant root initiation for the seed was determined according to AOSCA (2003). Each growth pouch was examined daily for up to 28 days.

In the space-planted field trials for cultivar evaluation, seedling establishment and subsequent stand persistence were measured as plant frequency using a modified Vogel frame (see Section 6.5, Sampling Protocol).

All data were subjected to analysis using the MIXED procedure of SAS Institute, Inc. (SAS) and replications were considered random, and the SOLUTION option was used to allow estimation of LS Means (Least Squares Means) (SAS, 1999). All mean separations were made on the basis of least significant differences at the 0.05 probability level. Forage yields or dry weights were also measured (see Section 6.5, Sampling Protocol).

6.5 SAMPLING PROTOCOL

This section describes each measuring technique used in the various parts of our demonstrations. Sampling dates are given in the timeline in Table 6; soil data protocols used before and after tracking are summarized in Table 7; Table 8 summarizes the type of vegetation sampling and number of samples at each demonstration site.

Table 8. Summary of vegetation sampling protocol at each site.

Site	Establishment	1 Year	2 Years	3 Years	4 Years
YTC	48-grid frame 4 reps; 4 samples/rep	24-grid frame 4 reps; 3 samples/rep	24-grid frame 4 reps; 5 samples/rep	---	---
Guernsey River site	48-grid frame; 3 reps; 3 samples/rep	24–grid frame 3 reps; 3 samples/rep	Visual ratings (3 teams of 2 people)	---	---
Guernsey Tower site	48-grid frame; 3 reps; 3 samples/rep	Visual ratings (3 teams of 2 people)	---	---	---
Dugway	48-grid frame; 4 reps; 3 samples/rep	---	---	---	---
Drum Area 8	---	24-grid frame; 4 samples/plot	---	---	---
Drum Airport	---	24-grid frame 4 samples/plot	36-grid frame; 4 samples/plot	36-grid frame; 4 samples/plot	36-grid frame; 4 samples/plot
YTC tracking plant cover	24-grid frame 4 reps; 5 samples/rep	24-grid frame 4 reps; 3 samples/rep	24-grid frame 4 reps; 3 samples/rep		

6.5.1 Vogel Frequency Frame (Modified)

For most of our establishment and persistent measurements, we used a modified Vogel frame with an internal grid (Vogel and Masters, 2001). Different sized grids were used. The grids consist of a metal frame containing 24, 36, or 48 squares created by heavy duty wire; the squares are aligned in a six-by-four, six-by-six, or six-by-eight pattern, and measure 12.7-by-12.7 cm (5-by-5 inch) in the 24-square frame or 6.35-by-6.35 cm (2.5-by-2.5 inch) in the 36- and 48-square frames. We randomly or systematically placed the grid within a seeded area. The number of cells containing plants were counted and converted into frequency of occurrence or stand percentages by dividing the number of cells that contain a seeded plant by the total number of squares counted. Similar methods are used to obtain percent bare ground, percent dead plants, or percent weeds.

6.5.2 Visual Frequency Ratings

At some sites, we recorded a visual rating of ground cover, weeds, litter, and bare ground. Three teams of two rated each plot overall, and their values were used to get the percentages.

6.5.3 Plant Biomass (Forage Yield)

Plant biomass (forage yield or dry plant matter) was evaluated in the spaced-plant nurseries. At some locations, individual plots were harvested with a sickle-bar harvester to an 8-cm stubble height just prior to anthesis. Forage samples were taken from each plot and dried to a constant weight in a forced-air oven at 60°C for 48 hours to determine dry matter percentage.

6.5.4 Shear Strength

Soil shear strength was measured with a Pilcon shear vane (ELE model CL-612 Hand Vane Tester). Measurements were made in three to five locations in a 12-inch x 12-inch area from the center of the right track in each plot (Figure 7). The five values were then averaged to give the shear strength for that. Soil shear strength was taken immediately before the traffic event at YTC Exit 11 June 2005.

6.5.5 Soil Moisture

Soil moistures were measured in the same three- to five-measurement pattern (Figure 7) with a Delta T type ML2x probe/HH2 moisture meter from each replication prior to tracking and averaged to give the moisture in that plot.

6.5.6 Soil Bulk Density

Bulk density measurements were taken with a 283 cm^3 drive cylinder corer in the zero-pass treatment, from 10 plots.

6.5.7 Soil Compaction (Penetration Resistance)

A drop-cone penetrometer was used to measure soil compaction before tracking in the zero-pass treatment and immediately following tracking in the low- and high-rate plots. All compaction measurements were taken from the left-hand track (looking in the direction of vehicle movement) with two samples per species (plot) averaged to give depth of penetration for each plot.

6.5.8 Rut Depth

Rut profiles were taken from the right-hand track with a pin profilometer as described by Affleck et al. (2004) (Figure 8). Profiles for the four-pass treatments were taken in every plot for all replications, for the one-pass treatment from five plots for each replication, and for the zero-pass treatments from three plots.

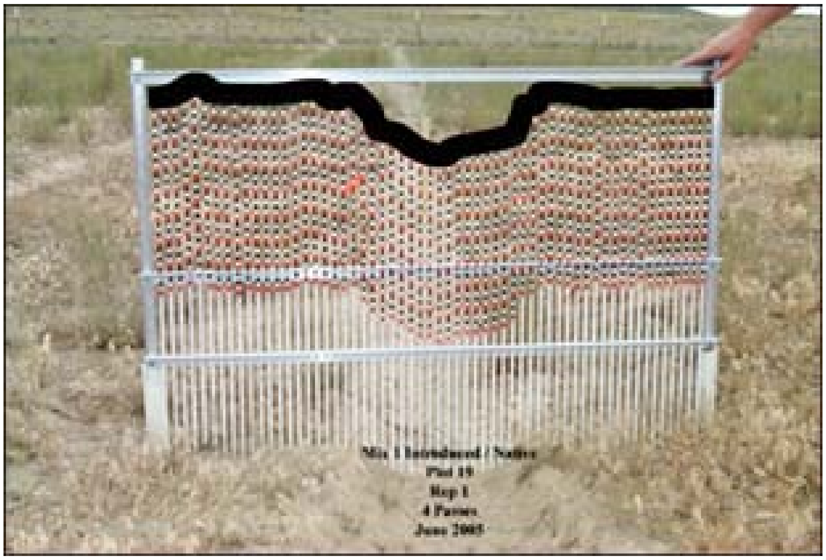

Figure 8. Pin profilometer used in a four-pass rut immediately after tracking in June 2005.

6.5.9 Statistical Analyses

Differences in establishment rates and persistence between the SERDP-select germplasms and standard cultivars were done with multiple means comparison tests (protected least significant difference [LSD]). Differences in the establishment rate, growth of invasive plants, and plant regrowth after tracking of the eco-bridge seeds were subjected to analysis of variance using PROC MIXED (SAS, 1999), with entries as fixed and replications and years as random variable effects. Mean separations were made on the basis of the LSD test at an alpha = 0.05 probability level.

6.6 SAMPLING RESULTS

These sections provide summary data and figures of our results; details are provided in the Final Report for this project.

All the demonstration plots were seeded before most of the modified germplasms had been named and released. At that time, the modified seeds were referred to as SERDP-select. For clarity in this summary section, we refer to those modified plant materials by their release names, with the exception of Snake River wheatgrass, which has not yet been released or named.

6.6.1 Field Evaluations of New Germplasms: Comparisons of Germplasms with Existing Cultivars (Monocultures)—Results

6.6.1.1 <u>Yakima Training Center Monocultures</u>

Table 9 and Figures 9 and 10 show stand establishment and percent stand over 3 years from the Exit 11 seeding on October 21-22, 2002. Variety names are given in parentheses; the SERDP-modified entries are shaded in green. The SERDP-modified entries generally did better than the standard cultivars; the SERDP cultivars of Siberian wheatgrass and western wheatgrass had significantly better cover than their counterparts in all 3 years. In the last year, 2005, the

vegetation was very uneven, several species were nearly gone, and the plots were infested with bill bugs. Precipitation on the plots had been sparse for some time, and the soil was very dry. Only a few plots with Vavilov and SERDP-modified Vavilov-II Siberian wheatgrass, SERDP Recovery western wheatgrass, and SERDP Bozoisky-II parent Russian wildrye were reasonably covered.

Table 9. Establishment and persistence of monocultures for 3 years at Exit 11 YTC.
(Seeded October 21-22, 2002)

Variety	2003	2004	2005	LSD @0.05
Russian wildrye (Bozoisky II)	54	67	73	ns
Russian wildrye (Boz X Tet)	47	60	62	12.33
Siberian wheatgrass (Vavilov II)	52*	63*	73*	ns
Siberian wheatgrass (Vavilov)	23	35	51	9.33
Bluebunch wheatgrass (P-7)	30	47	48	ns
Bluebunch wheatgrass (Goldar)	32	39	40	ns
Slender wheatgrass (FirstStrike)	82*	69	21	15.66
Slender wheatgrass (Pryor)	49	48	28	ns
Snake River wheatgrass (SERDP)	28	41	54	17.49
Snake River wheatgrass (Secar)	40	58	54	13.87
Western wheatgrass (Recovery)	73*	81*	80*	ns
Western wheatgrass (Rosana)	40	53	59	ns
LSD @ 0.05	16.36	27.06	19.29	

* Significantly better than the equivalent standard cultivar in that year

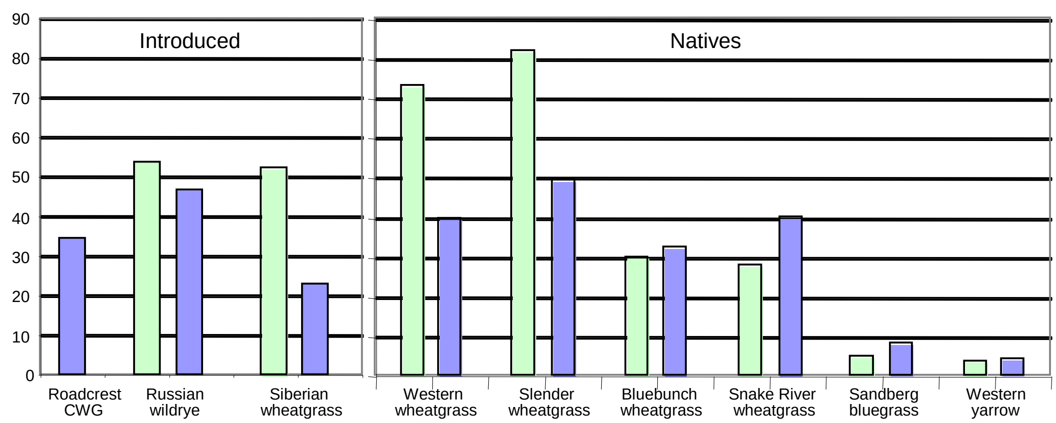

Figure 9. Percent establishment of modified germplasms (green) versus standard cultivars at Exit 11 YTC in May 2003, 6 months after seeding.

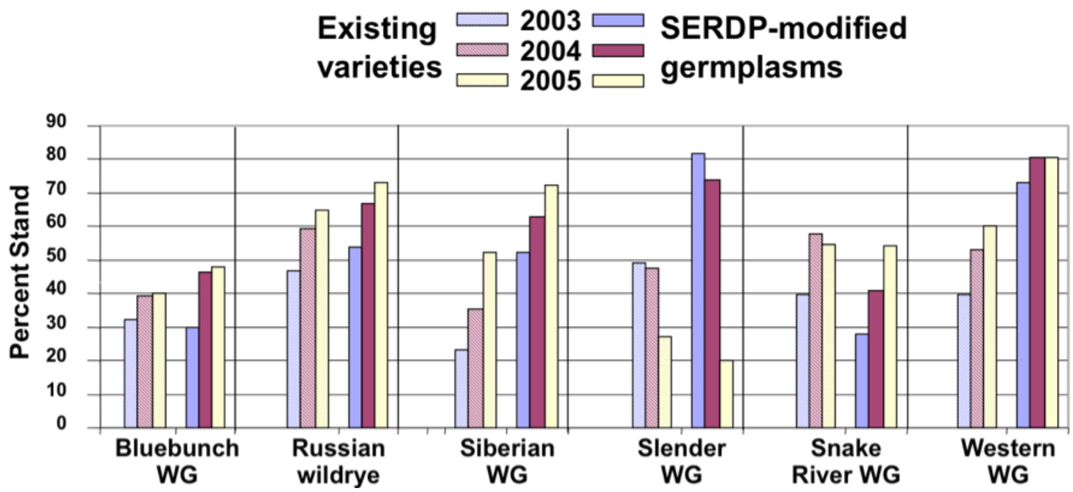

Figure 10. Percent stand vegetation from 2003 to 2005 (before June 2005 tracking at YTC).

6.6.1.2 Camp Guernsey Monocultures

Guernsey establishment (2 months after seeding). The River site was seeded March 31, 2004, and establishment measurements were taken June 2, 2004. The Tower site was seeded the following year, March 23, 2005, and establishment measurements were taken June 2, 2005.

Our FirstStrike slender wheatgrass established significantly better than Pryor slender wheatgrass at both sites, and our Bozoisky II Russian wildrye established significantly better than the standard Bozoisky cultivar at the River site (Table 10).

Table 10. Guernsey site establishment data at two sites taken 2 months after seeding.
(River site seeded March 31, 2004; data taken June 2, 2004;
Tower site seeded March 23, 2005; data taken June 2, 2005)

Entry	River % Stand at 2 Months	Tower % Stand at 2 Months
Introduced		
Russian wildrye (Bozoisky-II parent)	48*	50
Russian wildrye (Bozoisky)	17	65
Siberian wheatgrass (Vavilov II)	54	68
Siberian wheatgrass (Vavilov)	38	65
Native		
Western wheatgrass (Recovery)	61	51
Western wheatgrass (Rosana)	55	39
Slender wheatgrass (FirstStrike)	81*	62*
Slender wheatgrass (Pryor)	35	37
Bluebunch wheatgrass (P-7)	43	56
Bluebunch wheatgrass (Goldar)	47	55
Snake River wheatgrass (SERDP-select)	5	55
Snake River wheatgrass (Secar)	6	44
Basin wildrye (SERDP-select)	11	40
Basin wildrye (Trailhead Basin)	13	50
Western Yarrow (Yakima)	0	0
Western Yarrow (Check)	0	0
LSD @0.05	19	24

* Significantly better than equivalent standard cultivar

Guernsey persistence data (1-year and 2-years after seeding). Table 11 shows the 1-year data from both River and Tower sites; Table 12 shows 2-year data for the River site. We were unable to measure the Tower site after 2 years (2007) due to drought conditions.

After 1 year, our Bozoisky II Russian wildrye again had significant greater stand and fewer weeds than did the standard Bozoisky cultivar. After 1 and 2 years at the River site, our FirstStrike slender wheatgrass had significantly fewer weeds than did Pryor slender wheatgrass; after 2 years, FirstStrike had a significantly greater stand frequency than Pryor.

Table 11. Guernsey site persistence data at two sites taken 1 year after seeding.
(River site seeded March 31, 2004; data taken June 2, 2005;
Radar site seeded March 23, 2005, data taken July 19, 2006.

Entry	River Site at 1 Year (mean percent)		Tower Site at 1 Year (mean percent)	
	Stand	Weeds (visual est.)	Stand	Weeds (visual est.)
Introduced				
Russian wildrye (Bozoisky-II parent)	61*	30*	81	3
Russian wildrye (Bozoisky)	26	75	82	1
Siberian wheatgrass (Vavilov II)	68	2	91	4
Siberian wheatgrass (Vavilov)	63	2	77	3
Native				
Western wheatgrass (Recovery)	73	30	74	7
Western wheatgrass (Rosana)	77	30	78	3
Slender wheatgrass (FirstStrike)	65	17*	89	1
Slender wheatgrass (Pryor)	44	50	65	4
Bluebunch wheatgrass (P-7)	55	40	76	3
Bluebunch wheatgrass (Goldar)	38	37	81	2
Snake River wheatgrass (SERDP-select)	13	77	80	4
Snake River wheatgrass (Secar)	8	73	70	6
Basin wildrye (SERDP-select)	10	78	19	14
Basin wildrye (Trailhead Basin)	10	77	25	10
Western yarrow (Yakima)	0	90	1	22
Western yarrow (common variety)	0	87	3	22
LSD @0.05	26.8	26.7	26.7	7.9

* Significantly better than equivalent standard cultivar

Table 12. Guernsey River site persistence data 2 years after seeding.
(Seeded March 31, 2004; data taken July 19, 2006)

Entry	Mean percent (visual rating)				Frame Measure-ment
	Cover	Weeds	Litter	Bare Ground	Percent Stand
Introduced					
Russian wildrye (Bozoisky-II parent)	37	0	28	35	66*
Russian wildrye (Bozoisky)	24	4	21	51	32
Siberian wheatgrass (Vavilov II)	41	1	20	39	68
Siberian wheatgrass (Vavilov)	38	1	16	46	55

Table 12. Guernsey River site persistence data 2 years after seeding (continued).
(Seeded March 31, 2004; data taken July 19, 2006)

Entry	Mean percent (visual rating)				Frame Measurement
	Cover	Weeds	Litter	Bare Ground	Percent Stand
Native					
Western wheatgrass (Recovery)	44	1	23	31	91
Western wheatgrass (Rosana)	40	1	25	34	83
Slender wheatgrass (FirstStrike)	37	1*	19	43	62*
Slender wheatgrass (Pryor)	14	19	32	34	31
Bluebunch wheatgrass (P-7)	28	5	26	41	50
Bluebunch wheatgrass (Goldar)	24	7	19	50	43
Snake River wheatgrass (SERDP-select)	7	26	27	41	14
Snake River wheatgrass (Secar)	14	13	32	41	23
Basin wildrye (SERDP-select)	3	29	22	46	6
Basin wildrye (Trailhead Basin)	13	28	25	33	12
Western yarrow (Yakima)	0	35	32	33	3
Western yarrow (common variety)	0	36	31	34	0
LSD @0.05	16.5	17.3	ns	ns	29.8

* Significantly better than equivalent standard cultivar

6.6.1.3 Dugway Proving Ground Monocultures

We took establishment data only at DPG. The establishment was poor across all species at this very dry facility, so no further data were collected. The site was seeded on November 7, 2005, and the establishment data taken May 10, 2006. Establishment was poor overall, and the only significant differences between entries of the same species were for Siberian wheatgrass and slender wheatgrass (Table 13).

Table 13. DPG establishment data 6 months after seeding.
(Seeded November 7, 2005; data taken May 10, 2006)

Entry	Percent Stand
Introduced	
Russian wildrye (Bozoisky-II)	15.5
Russian wildrye (Bozoisky)	17.9
Siberian wheatgrass (Vavilov II)	33.3*
Siberian wheatgrass (Vavilov)	17.9
Native	
Western wheatgrass (Recovery)	11.6
Western wheatgrass (Rosana)	6.9
Slender wheatgrass (FirstStrike)	11.8
Slender wheatgrass (Pryor)	23.3
Bluebunch wheatgrass (P-7)	12.5
Bluebunch wheatgrass (Goldar)	4.9
Snake River wheatgrass (BC04)	9.4
Snake River wheatgrass (Secar)	8.2

Table 13. DPG establishment data six months after seeding (continued).
(Seeded November 7, 2005; data taken May 10, 2006)

Entry	Percent Stand
Basin wildrye (SERDP-select)	6.9
Basin wildrye (Trailhead Basin)	7.6
Western yarrow (Yakima)	0.3
Western yarrow (common variety)	0.0
LSD @0.05	7.7

* Significantly greater than the equivalent standard cultivar

6.6.2 Ecological-Bridge Demonstration (Mixtures) – Results

We were able to obtain 4 years of data on mixtures only at the Fort Drum Airport site. Our mixture evaluations at YTC and Fort Guernsey were hampered by severe drought conditions, and our second Fort Drum site was trained on after the first year.

6.6.2.1 Yakima Training Center Mixes

At YTC, there were no significant differences in the introduced/native and all native mixtures in each year after seeding (Table 14); see Table 3 for a list of the plants included in each mixture.

Table 14. YTC mixtures 6 months, 1.5 years, and 2.5 years after seeding.

Mixture	Mean Percent Stand (May 2003)	Mean Percent Stand (April 2004)	Mean Percent Stand (June 2005)
Mix 1 – Introduced/native	44	55	59
Mix 2 – All native	44	58	58

6.6.2.2 Camp Guernsey Mixes

The following data were obtained for the River Site at Camp Guernsey planted March 31, 2004. See Tables 3 and 4 for lists of the plants included in each mixture.

At the River site (Table 15), the core native mix with our Bozoisky II Russian wildrye (mix 7) appeared to do the best overall for percent stand and inhibition of weeds, although there were no significant differences in establishment or weed control after the establishment year. The standard Guernsey mix 3 had significantly lower establishment than all the other mixes, which had no significant differences among them.

Table 15. Camp Guernsey River site mixtures 2 months and 1 and 2 years after seeding.
(Seeded March 31, 2004)

Mixture	Mean Percent Stand	Mean Percent Weeds
June 2, 2004 (2 months after seeding)		
Mix 1 - Introduced / native	42	
Mix 2 – All native	51	
Mix 3 - Guernsey	16	
Mix 4 - Core native	55	
Mix 5 - Core + AI Intermediate wheatgrass	54	
Mix 6 - Core + Vavilov II Siberian wheatgrass	58	
Mix 7 - Core + Bozoisky II Russian wildrye	57	
LSD @ 0.05	19.8	
June 2, 2005 (1 year after seeding)		
Mix 1 – Introduced / native	63	17
Mix 2 – All native	76	30
Mix 3 - Guernsey	41	45
Mix 4 - Core native	63	37
Mix 5 - Core + AI Intermediate wheatgrass	73	22
Mix 6 - Core + Vavilov II Siberian wheatgrass	48	32
Mix 7 - Core + Bozoisky II Russian wildrye	71	17
LSD @ 0.05	ns*	ns
June 2006 (2 years after seeding) (visual ratings)		
Mix 1 – Introduced/native	35	2
Mix 2 – All native	26	14
Mix 3 - Guernsey	41	4
Mix 4 - Core native	37	4
Mix 5 - Core + AI Intermediate wheatgrass	26	2
Mix 6 - Core + Vavilov II Siberian wheatgrass	34	5
Mix 7 - Core + Bozoisky II Russian wildrye	43	0
LSD @ 0.05	ns	ns

*Not significant

At the Tower site (Table 16), the introduced native mix tested at YTC provided the best stand initially and after 1 year. After 1 year the introduced-native mix 1 was significantly better than both the native-only mix 2 and the Guernsey mix 3. The standard Guernsey mix 3 had a significantly lower stand than all the other mixes after 1 year. There were very few weeds with any of the mixes and no significant differences among the mixes. The decrease across all mixes in 2006 may have reflected the beginning of drought; because of severe dryness, we were unable to obtain any data in 2007.

Table 16. Camp Guernsey Tower site mixtures 2 months and 1 year after seeding.
(Seeded March 23, 2005)

Mixture	Mean Percent Stand	Mean Percent Weeds
June 2, 2005 (2 months after seeding)		
Mix 1 - Introduced / native	57	
Mix 2 – All native	50	
Mix 3 - Guernsey	25	
Mix 4 - Core native	47	
Mix 5 - Core + AI Intermediate wheatgrass	42	
Mix 6 - Core + Vavilov II Siberian wheatgrass	44	
Mix 7 - Core + Bozoisky II Russian wildrye	45	
LSD @ 0.05	ns	
June 2006 (1 year after seeding) (visual estimates)		
Mix 1 – Introduced / native	28	4
Mix 2 – All native	17	5
Mix 3 - Guernsey	9	5
Mix 4 - Core native	23	4
Mix 5 - Core + AI Intermediate wheatgrass	19	4
Mix 6 - Core + Vavilov II Siberian wheatgrass	24	4
Mix 7 - Core + Bozoisky II Russian wildrye	17	7
LSD @ 0.05	10.6	ns

6.6.2.3 Fort Drum Mixes

We took data at the Airport site for four years after the May 22, 2002 seeding but were able to obtain data only at the Area 8 site for 1 year. The Area 8 site had a good plant cover after the first year and was used for training after that.

Even after 1 year (Table 17), the native SG was doing very well, especially on the Area 8 site; the fescues were also doing well. The WL was beginning to die back at both sites. The HGs established in only one plot (plot 4 with WL and SG at Area 8).

Table 17. Fort Drum Area 8 1-year site percent cover and bare ground on June 24, 2003.

Treatment		WL	FF	SG	HG	Total Sown Species	Other Species	Dead WL	Bare Ground
1	WL	16	--	--	--	16	1	77	6
2	WL + HG	19	--	--	0	19	42	35	4
3	WL + SG	6	--	83	--	88	0	11	1
4	WL + SG + HG	1	--	83	4	87	0	12	0
5	WL + HG + SG + FF	0	42	2	0	44	0	44	2
6	WL + HG + FF	5	10	--	0	17	70	9	4
7	WL + SG + FF	4	62	2	--	64	0	33	2
8	WL + FF	54	18	--	--	58	0	42	0
	LSD @ 0.05	17	24	15	ns	23	13	20	ns

Over the next 4 years, the WL died off in all plots and the fescues did well in all plots where it was sown; the native HG failed in all plots. Percentages of undesired (other) species were low in all plots except plot 2, which was sown with WL with HG, both of which had died off. Figure 11 shows the results for the four plots (3, 4, 5, and 7) that contained SG. After 4 years, the SG was doing significantly better in those plots that did not contain fescues (3 and 4). In summary, the nurse crop did well during the initial year after seeding but was no longer competitive after 2 years; stands of predominately SG or fescues were created, giving a choice for the desired goal—a tall native stand or a lower growing more fire resistant stand of fescues.

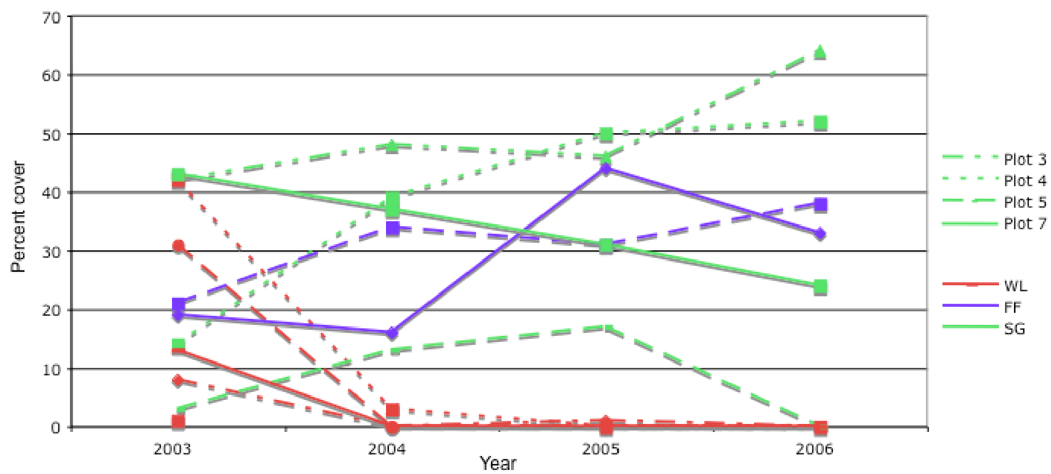

Figure 11. Airport site percent cover on the four plots seeded with SG.
(See Table 7 for seeding mixtures.)

6.6.3 Military Traffic on Monocultures at YTC—Results

Plots at YTC were tracked with zero, one, or four passes in June 2005; soil and vegetation data were taken immediately before and after tracking as well as 1 and 2 years later (June 2006 and 2007).

6.6.3.1 Soil Data

There were no significant differences in soil compaction by plant entry. Overall, increased tracking significantly decreased the soil strength and compaction immediately after the tracking (Table 18); tracking with a Stryker was similar to a tillage operation causing the soil to be fluffier with increasing passes. Shear vane measurements could not be taken immediately after tracking because of the soil disturbance. In succeeding years, any differences in soil compaction between treatments were slight, and the cone penetrometer values for the four-pass treatment were essentially the same as the control (zero-pass).

There was a significant increase in soil moisture in 2006 due to unexpected high rainfall (Table 18). The cone penetrometer data show significantly decreased soil compaction along with the increased soil moisture; by the following year, the soil was more compact, with values very close to those for 2005.

Table 18. Overall soil properties over 3 years after tracking in June 2005.

Year	Soil Moisture (%)	Shear Vane (kPa)*				Cone Penetrometer (cm)			
		0 pass	1 pass	4 pass	LSD @0.05	0 pass	1 pass	4 pass	LSD @0.05
2005	2.8	38.8	--	--	--	6.1	7.6	11.7	0.5
2006	14.3	38.1	36.4	24.6	ns	13.4	12.1	13.0	0.4
2007	3.3	37.6	35.8	24.1	ns	7.5	7.1	7.5	0.2
LSD @0.05	0.1	ns	.55	ns		0.5	0.4	0.5	

*kPa = kilo Pascal

Rut depth profiles did not differ significantly in the years following tracking, but mean rut depth (7 cm) immediately after the four-pass treatment was significantly different than for the one-pass treatment (4.2 cm) for all entries. The modified cultivars of Siberian wheatgrass, slender wheatgrass and Snake River wheatgrass had significantly lower rutting at one-pass treatment than their market competitors. Likewise the modified cultivars of Siberian wheatgrass, Russian wildrye, slender wheatgrass, and western wheatgrass had significantly lower rutting than their market counterparts at the four-pass treatment. The decreased rutting at one- and four-pass treatments indicates better root structure and resiliency than the other cultivar.

The mean value for soil bulk density (taken in zero-pass treatments in 2005) was 1.098 g/cm^3.

6.6.3.2 Vegetation Data

A summary of all plant cover data for the 3 years shows that each level of tracking was significantly different (Table 19). Similarly, there were significant differences in overall plant cover each year, showing the impact of heavy rains in 2006. The percent cover jumps from 38.7% (for all varieties and tracking levels combined) to 51.3% and then down to 44.4% for 2007. This effect is mirrored in the soil moisture data (Table 18).

Table 19. Summary data for tracking and annual effects on plant cover at YTC.

Tracking Effect			Yearly Effect		
Tracking	% Cover		Year	% Cover	
0 pass	51.1	a	2005	38.7	c
1 pass	26.4	b	2006	51.3	a
4 passes	4.28	c	2007	44.4	b
LSD @ 0.05	5.11		LSD @ 0.05	4.28	

Vegetative cover in the three years leading up to tracking is shown above under "(1) Field Evaluations of New Germplasms: Comparisons of Germplasms with Existing Cultivars (Monocultures)—Results" (Table 9, Figures 9 and 10). The SERDP-modified entries generally did better than the standard cultivars; the SERDP cultivars of Siberian wheatgrass and western wheatgrass had significantly better cover than their counterparts in all three years before tracking.

Throughout the post-tracking evaluations, three SERDP-modified entries—Snake River wheatgrass, Siberian wheatgrass, and Russian wildrye—performed better than the standard variety counterparts. Figure 12 compares the plant varieties for all tracking treatments combined immediately after and 1 year following tracking, and Table 20 shows the same comparisons for the duration of the tracking evaluation (2005-2007). Of note overall is the SERDP Snake River wheatgrass (74.1%) versus Secar Snake River wheatgrass (48.9%) and SERDP Siberian wheatgrass Vavilov II (72.5%) versus the standard Vavilov (45.5%). Both slender wheatgrass entries were low throughout, likely because of poor performance in the dry conditions preceding the tracking event.

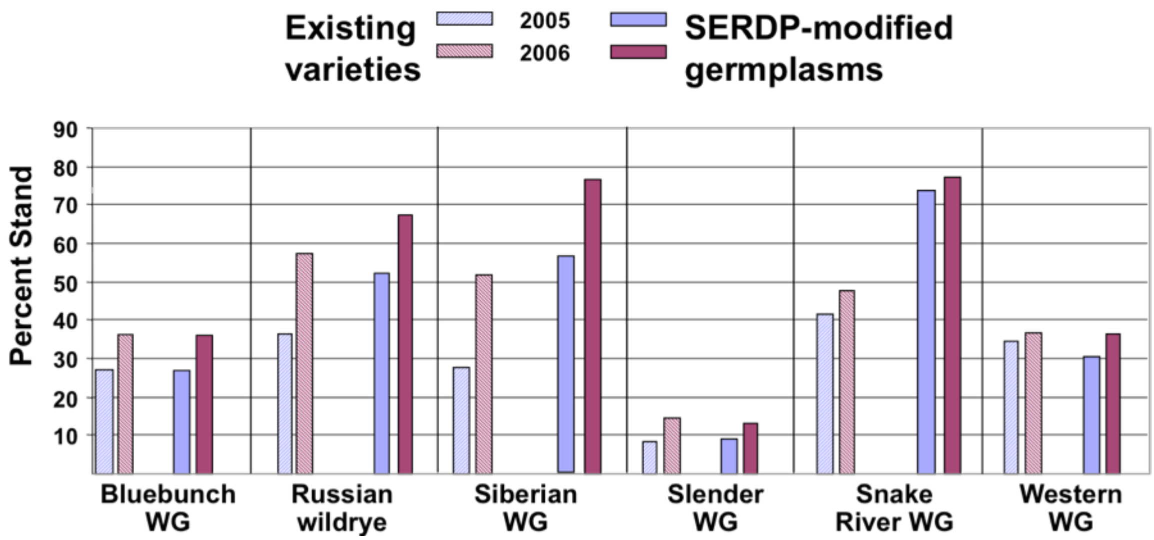

Figure 12. Percent stand vegetation immediately after and 1 year following 2005 tracking at YTC.
(Figure 13 shows percent stand for 2003-2005 before tracking.)

Table 20. Summary of plant cover for each entry over all treatments for 3 years after tracking (2005-2007) at YTC.

Entry	Percent Cover
Bluebunch wheatgrass (P-7)	36.6
Bluebunch wheatgrass (Goldar)	34.1
Russian wildrye (Bozoisky II)	59.7*
Russian wildrye (BozXTet)	43.7
Siberian wheatgrass (Vavilov II)	72.5*
Siberian wheatgrass (Vavilov)	45.4
Slender wheatgrass (FirstStrike)	12.6
Slender wheatgrass (Pryor)	13.5
Snake River wheatgrass (SERDP)	74.1*
Snake River wheatgrass (Secar)	48.9
Western wheatgrass (Recovery)	43.7
Western wheatgrass (Rosana)	53.8
LSD @ 0.05	8.57

* Significantly greater than the standard cultivar entry for this species.

Looking at tracking effects, all entries except Pryor slender wheatgrass had significantly less cover at the four-pass treatment as compared to the one-pass treatment (Table 21). Most entries had no significant difference in cover between the zero-pass control and one-pass treatment. Three of the SERDP-modified entries—Bozoisky II Russian wildrye, Vavilov II Siberian wheatgrass, and SERDP-select Snake River wheatgrass—did significantly better than the commonly available varieties for all treatments.

Table 21. Varieties showing significant differences at the different tracking passes over 3 years of data (2005-2007) after tracking at YTC.

	Tracking			
Entry	0 pass	1 pass	4 pass	LSD @0.05
Bluebunch wheatgrass (P-7)	63*	44.4	3.2	5.6
Bluebunch wheatgrass (Goldar)	41.2	47.2	13.9	16.5
Russian wildrye (Bozoisky II)	75.9*	63.9*	39.3*	15.8
Russian wildrye (BozXTet)	49.5	55.1	26.4	15.1
Siberian wheatgrass (Vavilov II)	81.5*	77.8*	58.3*	7.2
Siberian wheatgrass (Vavilov)	61.6	59.3	15.3	8.3
Slender wheatgrass (FirstStrike)	23.1	13.9	0.9	6.6
Slender wheatgrass (Pryor)	17.1	13.9	9.7	8.6
Snake River wheatgrass (SERDP)	78.2*	80.1*	63.9*	5.5
Snake River wheatgrass (Secar)	56	57.4	33.3	9.7
Western wheatgrass (Recovery)	64.8	48.6	17.6	6.9
Western wheatgrass (Rosana)	71.7	51.4	35.2	10.9
LSD @ 0.05	10.4	9.4	9.1	

* Significantly better than the equivalent standard cultivar for that treatment

6.6.4 Cultivar Validation: Germination and Nursery-Field Studies—Results

6.6.4.1 Germination Studies

In the growth-pouch germination studies, germination occurred at all the temperatures—10, 15, 20, 25, and 30ºC (33.8, 59, 68, 77, and 86ºF)—but there were significant differences between the lower and higher temperatures. The greatest percent germination occurred at 15ºC; the next highest rates were at 10 and 20ºC. Although germination occurred sooner at the higher temperatures, the percent germination was significantly lower at the two highest temperatures (Table 22).

Table 22. Temperature effects on all entries combined in germination growth pouch studies.

Temperature	Average Time to Germination (Days)	Percent Germination
10ºC	6.4	70.9
15ºC	5.7	76.2
20ºC	4.6	68.7
25ºC	4.8	58
30ºC	5.1	40.6
LSD @0.05	0.45	2.9

Tables 23 and 24 compare our four cultivars plus our modified Snake River wheatgrass (a potential cultivar) with currently available cultivars at the five temperature variables (green shading indicates our cultivars). FirstStrike slender wheatgrass germinated earlier than Pryor at the three lower temperatures. For the other species comparisons, there were no significant differences in time to germination at the individual temperatures (Table 23).

Table 23. Species comparisons of average days to germination in growth pouch studies.

Entry	Days to Germination					
	10°C	15°C	20°C	25°C	30°C	All Temps
Russian wildrye (Bozoisky II)	6.2	4.7	3.1	3.4	4.5	4.4
Russian wildrye (Bozoisky)	5.7	5	3.2	3.2	4.6	4.3
LSD @ 0.05	ns	ns	ns	ns	ns	ns
Siberian wheatgrass (Vavilov II)	4.9	4.3	3.5	3.4	4.2	4.1
Siberian wheatgrass (Vavilov)	5.3	4.6	3.6	3.8	4.1	4.3
LSD @ 0.05	ns	ns	ns	ns	ns	0.18
Slender wheatgrass (FirstStrike)	5.6	5	4.6	4.6	6.2	5.2
Slender wheatgrass (Pryor)	11.6	11.6	10.3	7.1	0	8.1
LSD @ 0.05	2.3	0.1	2.8	ns	2	1.7
Snake River wheatgrass (SERDP)	4.3	3.9	3.1	3.7	4.4	3.9
Snake River wheatgrass (Secar)	4.5	4	4.1	5.1	5.3	4.6
LSD @ 0.05	ns	ns	ns	ns	ns	0.3
Western wheatgrass (Recovery)	7	6	4.7	4.9	7.7	6.1
Western wheatgrass (Rosana)	8.4	7.3	4.3	5.3	7.2	6.5
LSD @ 0.05	ns	ns	ns	ns	ns	ns

For percent germination, our FirstStrike slender wheatgrass outperformed Pryor at all temperatures; both cultivars did poorly at the higher temperatures, but FirstStrike still outperformed Pryor. Our modified Snake River wheatgrass entry also outperformed Secar at all temperatures except 10ºC where there was no significant difference between the two. For the remaining entries, our modified cultivars were generally the same or slightly better for percent germination than the standard cultivars, although Bozoisky Russian wildrye had significantly greater percent germination at 10ºC than did our Bozoisky II entry, and Rosana western wheatgrass outperformed Recovery at the higher temperatures (Table 24).

Table 24. Species comparisons of average percent germination in growth pouch studies.

Entry	Percent Germination					
	10°C	15°C	20°C	25°C	30°C	All Temps
Russian wildrye (Bozoisky II)	57.5	74	86	62	68.5	69.6
Russian wildrye (Bozoisky)	92.5	96	88	95.2	78.5	89.5
LSD @ 0.05	24.7	ns	ns	ns	ns	6.4
Siberian wheatgrass (Vavilov II)	95.5	93	96	94	77	91.1
Siberian wheatgrass (Vavilov)	88.5	89	91	85	71	84.9
LSD @ 0.05	ns	ns	ns	ns	ns	3
Slender wheatgrass (FirstStrike)	89	94	81	66.5	33.5	89
Slender wheatgrass (Pryor)	38.5	50	14	3	1	38.5
LSD @ 0.05	14.3	3.7	16.5	14.5	28.7	14.3
Snake River wheatgrass (SERDP)	90	93	90	86.5	61.5	84.2
Snake River wheatgrass (Secar)	87	83	74	62.5	39	69.1
LSD @ 0.05	ns	8.1	11	10.7	18.1	4.2
Western wheatgrass (Recovery)	38.5	59	36	12	4.5	30
Western wheatgrass (Rosana)	31.5	43	31	36	18	31.9
LSD @ 0.05	ns	11	ns	20.3	ns	ns

When all entries were compared over all temperatures combined, three of our four modified native germplasms ranked in the top six for percent germination (Table 25).

Table 25. Overall comparisons with all temperatures combined in germination growth pouch studies.

Entry	Average Time to Germination (Days)	Percent Germination	Percent Rank
Basin wildrye (SERDP)	6.7	38.6	
Great Basin wildrye (Magnar)	5.6	71.5	6
Russian wildrye (Bozoisky II)	4.4	69.6	
Russian wildrye (Bozoisky)	4.3	89.5	2
Slender wheatgrass (FirstStrike)	5.2	72.8	5
Slender wheatgrass (Pryor)	8.1	21.3	
Snake River wheatgrass (SERDP)	3.9	84.2	4
Snake River wheatgrass (Secar)	4.6	69.1	
Siberian wheatgrass (Vavilov II)	4.1	91.1	1
Siberian wheatgrass (Vavilov)	4.3	84.9	3
Western wheatgrass (Recovery)	6.1	30	
Western wheatgrass (Rosana)	6.5	31.9	
LSD @0.05	0.7	4.6	

6.6.4.2 Space-Planted Nursery Studies

Data gathered in these trials were used, along with morphological and genetic characteristics, to support the releases of four cultivars under the ESTCP program.

Recovery western wheatgrass was selected for plant and seedling vigor, increased germination, and seed yield. During the spring of the establishment year, Recovery western wheatgrass had significantly higher ($P \leq 0.05$) frequency of seedlings (0.60) than parental/closely-related cultivars Rosana (0.48) and Rodan (0.45), and the western wheatgrass cultivars of Arriba (0.45), Barton (0.42), and Flintlock (0.53) when analyzed across all locations. Within locations, Recovery had significantly better establishment than Rodan in three of five test locations, and more than Rosana in three of eight test locations. On average, Recovery's establishment was better than Bozoisky Russian wildrye, similar to Bozoisky II and Vavilov Siberian wheatgrass, and lower than Vavilov II and Hycrest and Hycrest II crested wheatgrasses.

The ability of seedlings to survive the first year after planting can be difficult due to competition from invasive annual and biennial grasses and forbs that benefit from the disturbed, open environment. Across locations, Recovery western wheatgrass had significantly ($P \leq 0.05$) more surviving plants (frequency of 0.77) the year after establishment than parental/closely-related cultivars Rosana (0.68) and Rodan (0.66), and the western wheatgrass cultivars of Arriba (0.63), Barton (0.68), and Flintlock (0.66). In fact, Recovery had higher frequency ($P \leq 0.05$) of plants than any other western wheatgrass cultivar until the fourth to sixth year after planting (Figure 13).

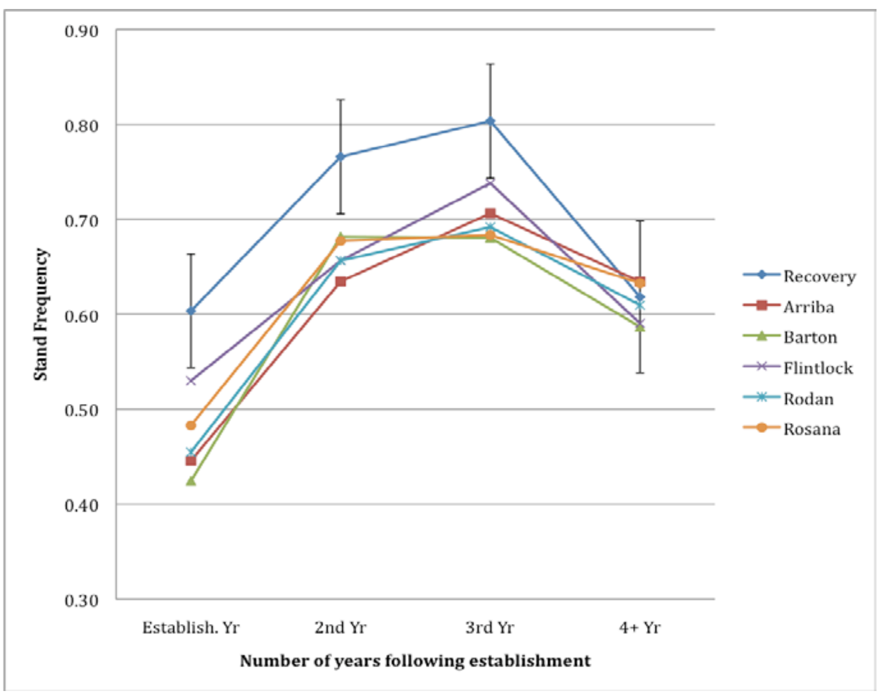

Figure 13. Stand of recovery western wheatgrass as compared to standard western wheatgrass checks when evaluated at eight locations throughout the western United States. Error bars are the LSD value at the P=0.05 probability level. The "4+Yr" category is the latest evaluation taken at a given site and ranges from 4 to 6 years after planting. (Waldron et al., in press)

Forage yield (dry matter yield) of Recovery western wheatgrass was not significantly different from other western wheatgrass cultivars at the Blue Creek, UT, location and the Curlew Valley, ID, location with the exception of a higher yield than Rosana at Curlew Valley. However, at Nephi, UT, Recovery forage yield was significantly lower than all other western wheatgrass cultivars except Arriba. Overall, these results suggest that Recovery will yield comparable or slightly less than other western wheatgrasses.

FirstStrike slender wheatgrass was selected for persistence and overall plant vigor in response to drought. It had significantly ($P<0.05$) more seedlings per unit area (m^2) than Pryor in the establishment year (Tables 10, 26, 27). At Fillmore, UT, and Malta, ID, initial stand and persistence of FirstStrike were similar to the cultivar San Luis. FirstStrike was similar to or better than Pryor and San Luis for persistence. At Guernsey, WY, dry matter yield was 27% greater ($P<0.07$) in FirstStrike than Pryor. FirstStrike germinated five days earlier than Pryor on three different soil types (sandy loam, loam, and sandy) than Pryor.

Table 26. Stand establishment and persistence over 1 year at two Filmore, UT, sites, established fall 2003 (Site 1) and 2004 (Site 2).

(Jensen et al., 2007)

Entry	Site 1			Site 2
	Estab. 2004 (%Stand)	Persistence 2005 (% Stand)	Persistence Comb 04-05 (% Stand)	Estab. 2005 (% Stand)
Siberian wheatgrass (Vavilov)				54
Siberian wheatgrass (Vavilov II)				79
Trailhead Basin wildrye				33
Snake River wheatgrass (Secar)	38	55	47	41
Snake River wheatgrass (SERDP Select)	64	68	66	58
Bluebunch wheatgrass (Goldar)	67	67	67	81
Bluebunch wheatgrass (P7)	60	66	63	48
Slender wheatgrass (Pryor)	34	44	39	50
Slender wheatgrass (San Luis)				87*
Slender wheatgrass (FirstStrike)	81*	90*	85*	78*
Western wheatgrass (Rosana)	73	90	81	57
Western wheatgrass (Flintlock)	84	83	84	__
Western wheatgrass (SB-2)	88	89	89	67
Western wheatgrass (Recovery)	49	74	69	62
LSD (0.05)	21	20	18	21

*FirstStrike was significantly better than the cultivar Pryor slender wheatgrass.

Table 27. Stand establishment at Malta, ID, site, established fall 2004.
(Jensen et al., 2007)

Entry	Establishment Year 2005 (% Stand)
Siberian wheatgrass (Vavilov)	92
Siberian wheatgrass (Vavilov II)	95
Snake River wheatgrass (Secar)	79
Snake River wheatgrass (SERDP Select)	85
Bluebunch wheatgrass (Goldar)	79
Bluebunch wheatgrass (P7)	88
Slender wheatgrass (Pryor)	36
Slender wheatgrass (San Luis)	76
Slender wheatgrass (FirstStrike)	86*
Western wheatgrass (Rosana)	45
Western wheatgrass (Barton)	55
Western wheatgrass (SB-2)	68
Western wheatgrass (Recovery)	67#
LSD (0.05)	13

*FirstStrike was significantly better than the cultivar Pryor slender wheatgrass.
Recovery was significantly better than the cultivar Rosana western wheatgrass.

Vavilov II Siberian wheatgrass was selected for seedling and vegetative vigor, seed yield, and early spring green-up. During the establishment year, Vavilov II Siberian wheatgrass had significantly ($P<0.05$) higher numbers of seedlings per unit area (m^2) than Vavilov at YTC (52 versus 23%), Fillmore (79 versus 54%), DPG (79 versus 52%), and Curlew Valley (70 versus 40%) (Figure 14). In persistence after establishment, as measured by percent stand, Vavilov II was significantly more persistent than Vavilov at YTC (68 versus 44%), Fillmore (84 versus 62%), Curlew Valley (69 versus 55%), and Malta (97 versus 91%) (Figure 15). Dry matter yields (64 cm x 38cm plot) combined across YTC and Camp Guernsey were significantly ($P<0.05$) greater in Vavilov II (53 g $plot^{-1}$) than Vavilov (39 g $plot^{-1}$).

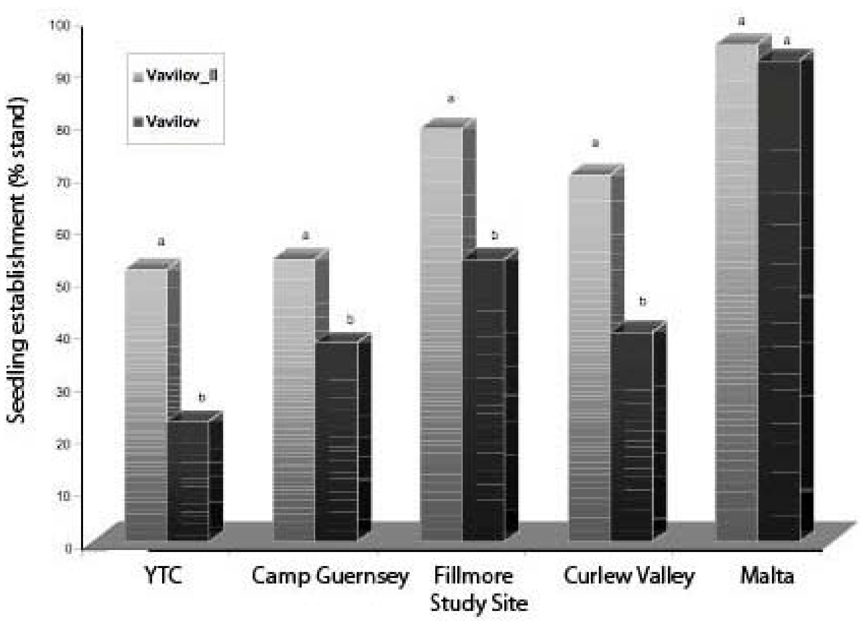

Figure 14. Seedling establishment for Vavilov II Siberian wheatgrass at five sites.
(Jensen et al., 2009)

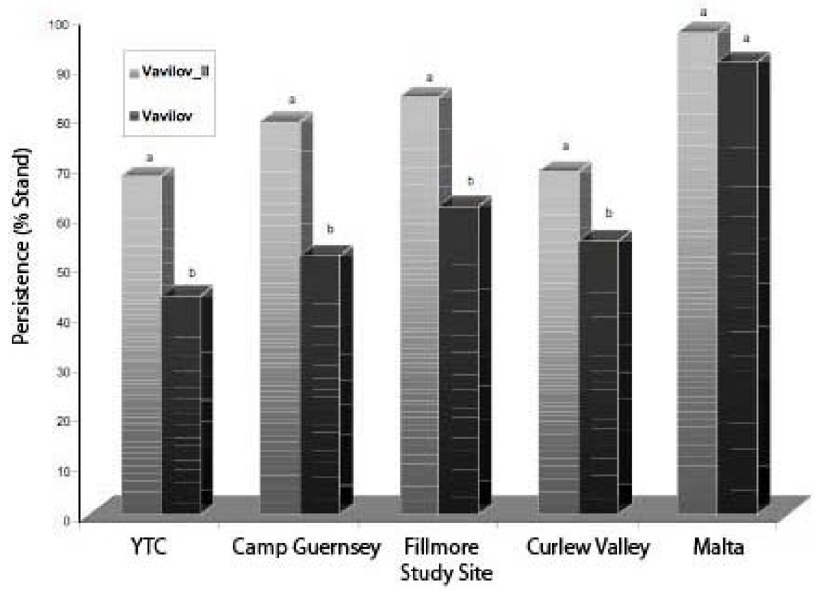

Figure 15. Persistence for Vavilov II Siberian wheatgrass at five sites.
(Jensen et al., 2009)

Bozoisky II Russian wildrye was selected for improved seed germination and seedling vigor. Bozoisky-II was evaluated in the NPA Regional Trials established in 1999 for initial stand, persistence, and dry matter forage production. Initial stands and persistence of Bozoisky-II were similar to Bozoisky-Select and Mankota combined over and within locations. However, Bozoisky-II established significantly better and yielded greater than the tetraploid cultivar Tetracan and the tetraploid germplasm Tetra-1 (Jensen et al., 1998). Dry matter yields of Bozoisky-II, Bozoisky-Select, and Mankota were similar except at Green Canyon, UT, where Bozoisky-II had significantly greater ($P<0.05$) yield than Mankota.

7.0 PERFORMANCE ASSESSMENT

The sections below discuss each performance objective shown in Table 2.

7.1 IMPROVED ESTABLISHMENT OF MODIFIED GERMPLASMS

This objective was met for our four new cultivars. In field-spaced nursery trials, the cultivars Bozoisky-II Russian wildrye, FirstStrike slender wheatgrass, Recovery western wheatgrass, and Vavilov II Siberian wheatgrass had significantly ($P<0.05$) greater stand establishment than base population cultivar after one or more years as detailed below.

Recovery western wheatgrass was selected for seedling vigor and quick establishment under rangeland conditions. It was evaluated extensively at semiarid sites representative of different ecological regions in northern plains and the western United States. Overall, it has shown superior and faster seedling establishment compared to commercially available cultivars Arriba, Barton, Flintlock, Rodan, and Rosana (Waldron et al., in press). Across locations, Recovery had higher frequency ($P\leq0.05$) of plants than any other western wheatgrass cultivar until the fourth to sixth year after planting (Figure 13). The rapid establishment of Recovery, in comparison to other western wheatgrass cultivars, will allow land managers to use this native grass species to help limit weed infestation and soil erosion in areas where the regularity of disturbances normally prevents western wheatgrass from becoming fully established (Waldron et al., 2006, in press).

Bozoisky-II Russian wildrye had significantly ($P\leq0.05$) more seedlings per unit area than two other Russian wildrye germplasms in the study (Jensen et al., 2006). Selection emphasis on Bozoisky-II was for increased seedling vigor during establishment.

During the establishment year, Vavilov II Siberian wheatgrass had significantly ($P<0.05$) higher numbers of seedlings per unit area at five locations.

FirstStrike slender wheatgrass was selected for persistence and overall plant vigor in response to drought. Although selection emphasis was not on seedling establishment, it appears than an increase in seedling vigor was correlated with the selection for persistence and plant vigor under extremely dry conditions in this population. In seeded trials at four sites, FirstStrike had significantly ($P<0.05$) more seedlings per unit area (m^2) than did the cultivar Pryor slender wheatgrass in the establishment year (Tables 10, 26, 27). FirstStrike germinated five days earlier than Pryor on three different soil types (sandy loam, loam, and sandy) than Pryor (Jensen et al., 2007) and at all but one temperature in growth pouch studies (Table 23).

7.2 RELEASE OF NEW GERMPLASMS

We met this objective by releasing six germplasms under the ESTCP program with a seventh currently in preparation. Four of those releases are cultivars and are discussed in the next section. Reliable Sandberg bluegrass and Yakima western yarrow were released as pre-variety germplasms (see Appendix C for a discussion of release types).

Yakima western yarrow was released as a source-identified class germplasm (Waldron et al., 2006b). The diversity within this germplasm is evident in the range of phenotypic differences

found in the Generation G1 field. The field of G1 generation Yakima western yarrow showed excellent, vigorous growth in Cache County, UT. Yakima was successfully established in a field trial at the YTC, and an earlier western yarrow collection (1994) from the same 26 locations was tested at the YTC where it established and persisted much better than common variety-not-stated western yarrow. Yakima western yarrow is intended for use in rehabilitation and restoration of western rangelands. It should be particularly useful to help stabilize and add diversity to severely disturbed sites, such as military training lands and after wildfires.

Reliable Sandberg bluegrass was released as a selected-class germplasm (Waldron et al., 2006a). It was successfully established in several trials in Utah and Idaho and at YTC. Sandberg bluegrass is an important understory grass in the bluebunch wheatgrass–sagebrush ecological sites of the Intermountain and Northwest regions of the United States. It is a medium-lived, perennial bunchgrass valuable for soil erosion control, spring livestock and wildlife grazing, and biodiversity. It resists trampling and is often one of the first species to reestablish on sites disturbed by fire, large equipment and vehicles, and animals. Reliable's intended use is for rehabilitation and restoration of western rangelands. It may be particularly useful as a pioneer plant species on severely disturbed sites, such as military training sites and after wildfires.

7.3 RELEASE OF NEW CULTIVARS

We exceeded our goal of releasing two or more germplasms as cultivars under the ESTCP program. Four SERDP-select plant germplasms were released as cultivars with the potential for PVP based on their breeding history and their response to selection for seedling vigor, persistence, and ability to regrow after disturbance. A minimum level of significance was set at alpha=0.05, and SERDP-select materials were tested against these criteria. A fifth cultivar release of Snake River wheatgrass is possible in the next couple of years.

"Bozoisky-II" Russian wildrye was released in 2005 (Jensen et al., 2006). Bozoisky-II was selected for seedling vigor (emergence from a deep planting depth), seed mass, seed yield, vegetative vigor, total dry matter production, and response to drought. Bozoisky-II has a much broader genetic base than other Russian wildrye cultivars and has been evaluated extensively on rangeland sites in the western United States. Seedling establishment of Bozoisky-II has been equal to or greater than commercially available cultivars. Within the Great Basin and Northern Great Plains, Bozoisky-II is adapted to sagebrush, mountain-brush, and pinyon-juniper on arid to semiarid rangelands. It is best adapted to loam and clay soils; however, acceptable stands can be obtained on a wide range of soil types. Russian wildrye's resistance to drought exceeds that of crested wheatgrass (Asay and Jensen, 1996).

"FirstStrike" slender wheatgrass was released in 2006 (Jensen et al., 2007). FirstStrike was selected for persistence and overall plant vigor in response to drought. FirstStrike is a multi-origin composite of four collections from Colorado and Wyoming and has been evaluated extensively on rangeland sites in the western United States with seedling establishment equal to or better than commercially available cultivars.

"Vavilov II" Siberian wheatgrass was released in 2008 (Jensen et al., 2009). Vavilov II was developed for reseeding sandy soils on disturbed rangelands dominated by annual weeds as a result of severe disturbance, frequent fires, and soil erosion. Selection emphasis was on seedling

establishment and plant persistence. The development of Vavilov II gives land managers new plant materials with enhanced seedling establishment and persistence on dry harsh rangelands.

“Recovery” western wheatgrass was released in 2009 (Waldron et al., in press). Recovery was developed for reseeding rangelands following severe disturbance, frequent fires, and soil erosion. Selection emphasis in Recovery was on improved and faster seedling establishment. During the establishment year, Recovery had increased frequency of seedlings when averaged across eight locations than “Arriba,” “Barton,” “Flintlock,” “Rodan,” and “Rosana” western wheatgrasses. Recovery continued to have superior stand until 4 to 6 years after planting when, due to their rhizomatous nature, all the western wheatgrasses were equal. Recovery is especially intended for revegetation of frequently disturbed rangelands, military training lands, and areas with repeated wildfires.

7.4 IMPROVED RESILIENCE OF MODIFIED GERMPLASMS TO MILITARY TRAFFIC

Three of the SERDP-modified entries—Bozoisky II Russian wildrye, Vavilov II Siberian wheatgrass, and SERDP-select Snake River wheatgrass—did significantly ($P<0.05$) better than the commonly available varieties for all treatments. All entries, except for Pryor slender wheatgrass, had significantly less cover at the four-pass treatment as compared to the one-pass treatment. A large jump in soil moisture 1 year after tracking resulted in a higher overall plant cover, making it harder to discern what was happening as a result of the tracking.

7.5 IMPROVED ESTABLISHMENT OF NATIVE GRASS STANDS

We studied the improved establishment rates of native plants using various mixed seedings at three locations (YTC, Camp Guernsey, Fort Drum). At all three locations in two climatic areas, we obtained native plant stands by combining native and introduced species together. Although there were few significant differences among the mixes, all of our mixes established significantly better ($P<0.05$) than the standard Guernsey mix at the Guernsey River site. At the Guernsey Tower site after 1 year, all mixes had significantly greater cover than the Guernsey mix, and the introduced-native mix 1 had significantly greater stand than the native only mix 2. At Fort Drum, we were able to obtain a stand of SG in 4 years.

7.6 REDUCTION OF NOXIOUS WEEDS ON TRAINING LANDS

Although we found no significant differences at YTC or Guernsey, the highest percent weeds were found with the all native mix 2 and core native mix 4 at the Guernsey River site after 2 years. At Fort Drum, we did not test an all-native mix, but weed percentages were very low in all introduced-native mixes except the WL-HG mixture after 4 years; the native HG was not successful in any mixture, and the WL had died back after 4 years, allowing undesired species to move in.

In earlier work at Fort Carson, which we used for our cost assessment analysis, we also showed reduction in weed stands across all our mixtures after 3 years.

7.7 QUALITATIVE RESULTS

7.7.1 Reliability

We have shown the reliability of the modified germplasms with successful plantings at four facilities in two climatic areas. Across all studies, the germplasms were able to establish and grow within the 4-year time frame of this demonstration. The germplasms were able to survive under various settings, including military vehicle tracking and different climatic regimes.

7.7.2 Ease of use

All seedings were completed with conventional no-till seeding equipment, which is a one-pass procedure in wide use at military facilities. The modified germplasms and ecological-bridge mixtures require no additional equipment, labor, or skills.

7.7.3 Versatility

As noted above, we have demonstrated successful and improved performance in a variety of locations under different conditions.

7.7.4 Maintenance

No maintenance is required.

7.7.5 Availability of Seed

Because there is no significant increase in cost to use our modified plants or seeding methods, the only barrier to implementation of the technology would be the cost and availability of seeds of the modified varieties. One of our goals was to convince producers to grow the seed in large enough quantities to make their prices comparable to those already on the market.

We entered into a contract with the USDA-NRCS Plant Material Center in Aberdeen, ID, to produce seed of new SERDP select germplasms of three species. About 5200 pounds of seed were produced for distribution to military facilities in FY07, and a comparable amount of seed was produced in FY08. The seed was distributed to YTC, Mountain Home Air Force Base in Idaho, Fort Carson, Camp Williams in Utah, Camp Guernsey, and Fort Riley in Kansas. Our first sale of seed to a commercial producer was completed in 2007. The producers purchased 300 lb of ‘FirstStrike’ slender wheatgrass foundation seed that will result in 36,000 lb of seed for sale at a value of $270,000.

The seeds for many of these germplasms should be available for some time; additional growers are producing seeds for retail sale, and the USDA-NRCS is recommending some of these germplasms for seeding to restore lands.

7.7.6 Awareness of Seed Capabilities and Planting Methods

To help market the new germplasms, we prepared two white papers describing the release of the new germplasms and their potential vulnerability and resistance to invasive species: “Decision Paper on Public Releases for the Germplasms Developed under the SERDP and ESTCP

Programs" (Appendix B) and "Implementation and Commercialization of New Germplasms for Use on Military Ranges."

The demonstrations studies conducted during this program were made available for inspection by land managers in the Intermountain West and Northeast United States climatic regions. We also visited and gave presentations about our modified germplasms and ecological-bridge mixtures at several military facilities and at professional and military-related meetings.

We partnered with the AEC to prepare a planting guide for the guidance in selecting appropriate ecological-bridge seed mixtures (Palazzo et al., 2009). We are currently expanding our geographic area in promoting the ecological bridge concept to military bases in Hawaii and the Southeastern United States.

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8.0 COST ASSESSMENT

This cost assessment is based primarily on work performed earlier at Fort Carson. Those results are summarized in Section 3.1.

8.1 COST MODEL

The Environmental Cost Analysis Methodology (ECAM) tool is designed to facilitate the gathering and analyzing of economic data in a manner that will allow for more accurate evaluation of investment in pollution prevention technologies. Our project did not involve hazardous waste materials, and as such, we do not meet the criteria for environmental reporting requirements and we have not used the ECAM tool.

In our project, we used equipment that is similar to or the same as equipment that is already in place at the facilities in the project's application; the cost difference in the proposed process as compared to the current one is minimal. The only minor increased cost we can envision may be in the increased cost to purchase the new seeds initially. With greater demand, the cost of the seeds should decrease and be comparable to those currently on the market, which should ultimately lead to reduced overall costs. Table 28 summarizes the costs related to revegetation with our modified germplasms and ecological-bridge mixtures. Section 8.3 includes information on costs related to current revegetation practices.

Table 28. Cost model for seeding modified germplasms or ecological-bridge mixtures.

Cost Element	Data Tracked during the Demonstration	Estimated Costs
Seed costs	Modified germplasms, new cultivars	Possible increase in seed costs for new germplasms and cultivars
Installation costs	Labor, equipment, and chemicals needed to seed	No change from normal operations
Operation costs	None necessary	None
Monitoring costs	None necessary	None
Maintenance	Reseeding requirements	No or reduced need to reseed

8.2 COST DRIVERS

No new equipment, skills, health and safety requirements, or regulatory standards are needed to use the new germplasms or seeding methods. Existing equipment and no-till seeding methods can be employed to seed the new varieties and mixtures. The key to "implementation" of this methodology is the proper decision making for selecting appropriate revegetation materials. We prepared a planting guide (Palazzo et al., 2009) that includes detailed information on plant selection for specific microclimatic ranges, training scenarios, and locations for optimal uses for each improved germplasm, as well as guidelines for selecting appropriate ecological bridge seed mixes.

The factors affecting cost and performance are the availability and cost of the improved germplasms and cultivars, and the cost savings resulting in improved performance of the vegetation. Currently available planting equipment and skills are used with the new materials. The only differences are in which types of seeds or mixtures of seeds are planted. The seeds for the new plant materials are unlikely to differ greatly in cost from currently used cultivars.

Potential cost savings can be realized from (a) the ability to seed less frequently because of increased establishment rates and better wear resiliency, (b) a decrease in need to consider other methods of controlling invasive weeds, and (c) the reduced downtime on ranges that should lead to cost efficiencies in scheduling training programs.

Using native plant species over introduced plant species can increase seed costs significantly because the native species are not as widely used. However, the actual land preparation and seeding practices should remain the same with our modified germplasms and recommended mixtures, and the frequency should be reduced for reseeding operations and the amount of chemical or mechanical control of noxious weeds.

8.3 COST ANALYSIS AND COMPARISON

We provide a cost estimate for one example for cost savings at Fort Carson that considers the greater resilience of the new germplasms and the faster establishment rates of native plants using the ecological bridge mixtures (Table 29). However, it is difficult to obtain a cost comparison since our results provide choices to military land managers who have an array of considerations in obtaining a vegetative cover on military lands. Those considerations include the intensity of land use, the choice of native or introduced plants, and the degree of encroachment by noxious weeds. Each consideration requires different seed selections, as described in our planting guide (Palazzo et al., 2009).

We conducted one of our early tests on ecological-bridge seed mixtures at Fort Carson, comparing several test mixtures with the standard Fort Carson mix (Palazzo et al., 2003; see also Section 3.2 of this report). At the same time, we looked into current seeding practices on that facility because it is a good candidate for using the new germplasms and seed mixtures.

Land rehabilitation at Fort Carson currently averages about 4000 acres annually, for an annual cost of $260,000 (based on the cost of $65 per acre). The time required between reseedings is based on land use. Intensely used areas need to be seeded annually, and those with little or no use will probably never need reseeding. Moderately used lands are generally reseeded every 3-5 years, with an average of every 4 years. We believe that using our modified germplasms and new cultivars in the mixtures can conservatively extend the use of moderately used areas by at least 2 years; in other words, these areas would generally require reseeding every 6 years. The tables below show some calculations for cost savings based on the frequency of seeding these moderately used land areas.

Table 29 shows the average annual cost of seeding an acre of moderately seeded lands assuming a 4-year cycle for existing germplasms and a 6-year cycle for SERDP-modified germplasms. Depending on seed cost, there will be a savings of 28–33%.

Table 29. Approximate costs of seeding moderately used lands at Fort Carson.

	Existing Germplasms	New Germplasms at Same Seed Cost	New Germplasms with 20% Increase in Seed Cost
Seeding cost per acre	$65	$65	$70
Average time between reseedings	4 years	6 years	6 years
Average annual seeding cost per acre of moderately used land (cost per acre/years between seedings)	$16.25	$10.83	$11.67
Average annual seeding savings per acre of moderately used land	--	$5.42	$4.58
% annual savings		33%	28%

Although the number of moderately used acres needing to be sown changes annually, it usually turns out to be about 2000 acres at Fort Carson, accounting for about half of the estimated $260,000 annual cost of reseeding, or $130,000 per year. If we multiply the seeding cost/year ($130,000 per year) by the percent annual savings (33% and 28%), we have a reduced savings cost of $42,900 or $36,400 per year.

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9.0 IMPLEMENTATION ISSUES

The end users for the modified plant germplasms and seeding methods are land managers on military and other federal lands. They need to know that our seeds and planting methods will produce improved, low-maintenance results on their lands, and sufficient seeds must be available to them at a cost equal to or less than currently available plant materials. The seeds themselves may be used over a wide geographic area (Figure 5); the only “customization” required is selection of appropriate species for use at individual facilities in terms of soil type, land use, climate, and types of plants desired (native and/or introduced species).

The demonstrations described in this report should provide land managers with ample justification to use our new plant materials and suggested mixtures. Throughout the project, our demonstration plots at two military installations have been open to land managers to increase awareness and promote transfer of the technology. We have consulted, and will continue to consult, with military land managers at numerous sites by phone and in person. We have presented our findings at conferences, workshops, and other appropriate forums, such as ITAM meetings (Palazzo et al., 2006, 2007) and the Battelle Conference on Sustainable Range Management in New Orleans (January 2004). As appropriate or when requested, we will distribute copies of the official germplasm release notices along with our existing reports on our spring 2002 workshop on the modified germplasms (Hardy and Palazzo, 2002), our final SERDP report (Palazzo et al., 2003), our final ESTCP report, and the Planting Guide (Palazzo et al., 2009).

The Planting Guide (Palazzo et al., 2009) that we produced as part of this demonstration project provides the necessary information on the use of the modified germplasms with other compatible species in seeding mixtures, planting recommendations, and criteria to select appropriate ecological-bridge methods. The planting guide includes sections on land use in the western United States, along with detailed information on individual species. Each land use intensity and eco-region section gives suggestions for appropriate species and mixes for various training-land uses and vegetation goals. Users may then refer to the detailed species section for information on planting.

We decided to go through a public release of the seed as opposed to a private release. The advantages to a public release are that foundation seed used to produce seed commercially will be available to all growers, and the greater distribution should lower the cost of the seed. The disadvantage to the public release is that poor quality seed may be produced and hurt the reputation of the new germplasm. Also, since many growers have the new germplasm, some may be a reluctant to market the seed. We hope to overcome this by working with seed producers.

We made seed available to military land managers for demonstration purposes. Initially, we contracted with the USDA-NRCS Plant Material Center in Aberdeen, ID, to produce sufficient seed for selected military facilities at no cost; seed was distributed in FY07 and FY08. As the germplasms continue to prove themselves and the demand for the seed becomes known, we anticipate that commercial seed producers will be more interested in carrying the seeds for sale. Also, to support the use of our new germplasms, the USDA-NRCS has acknowledged the improved performance of our species by including several of our germplasms on their

recommended list that retail seed buyers use to select cultivars of various grass species. At this time, only SERDP FirstStrike Slender wheatgrass is available for commercial sale, and it was recently included in a Fort Carson seed purchase of $30,000.

Other military involvement related to this program:

- The results of the ecological-bridge research have been used for the last 8 years at Fort Drum to more effectively establish native plants on sandy soils. Our tests showed that the seed mixture allowed the military to use the land again in less time. In 2009, we held a meeting at Fort Drum to demonstrate this concept. Invited participants included people from Camp Ripley, Minnesota; Fort Bragg, North Carolina; Fort Indiantown Gap, Pennsylvania, and the AEC.

- YTC has been using the seeding recommendations provided for the past 2-3 years with good results, and their plan is to include other recommendations as they become available. Their direct claim is:

  > One of the most important aspects that has helped us has been the work you have done with improvement of the native species. In fact, we have developed some aggressive erosion control projects (stream bank sloping projects similar to what Jeff has done at Carson) for implementation this spring and summer that includes use of some of these native species for revegetation efforts. Having these species become available was a major factor in our decision to carry out this aggressive bank sloping effort because we knew revegetation would actually be the key to overall success. Without these species, the project would be dead on arrival at Yakima.

- YTC is also using our methods to reseed upland areas following disturbance. Both the Records of Decision (ROD) for the YTC Expansion and the Fort Lewis Stationing actions include requirements for continued upland reseeding of up to 4000 acres annually to mitigate impacts associated with erosion, surface water quality, and noxious weeds. These mitigation requirements are direct benefactors of this ongoing research effort to develop the various cultivars.

- Recently we have expanded the ecological bridge concept to military facilities in the Southeastern United States and Hawaii.

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APPENDIX A

POINTS OF CONTACT

Point of Contact	Organization	Phone Fax E-Mail	Role
Antonio J. Palazzo	ERDC-CRREL 72 Lyme Road Hanover, NH 03755	603-646-4374 Fax: 603-646-4785 Antonio.J.Palazzo@usace.army.mil	Lead Principal Investigator, project implementation and coordination, establishment studies, cultivar releases
Timothy J. Cary	ERDC-CRREL 72 Lyme Road Hanover, NH 03755	603-646-4358 Fax: 603-646-4785 timothy.J.cary@usace.army.mil	Establishment studies, plot monitoring
Kevin B. Jensen	USDA-ARS Forage and Range Research Lab 695 North 1100 East Utah State University Logan, UT 84322-6300	435-797-3099 Fax: 435-797-3075 kevin@ars.usda.gov	Plant-breeding, establishment studies, cultivar releases
Dick Gebhart	ERDC-CERL 2902 Newmark Drive Champaign IL 61826-9005	217-352-6511 , x6391 Fax: 217-373-7222 Dick.L.Gebhart@usace.army.mil	Data analysis
Larry Holzworth (retired)	USDA-NRCS. Federal Bldg., Room 443 10 East Babcock Street Bozeman, MT 59715-4704		Monitoring demonstration plots
Susan Hardy (retired)	ERDC-CRREL 72 Lyme Road Hanover, NH 03755		Project planning, documentation,
Janet Clark	Center for Invasive Plant Management (CIPM) Montana State University P.O. Box 173120 Bozeman, MT 59717	406-994-6832 Fax: 406-994-1889 cipm@montana.edu	Promoting the ecological bridge concept
Dustin Kafka	Wyoming National Guard Bureau (NGB) 5500 Bishop Blvd. Cheyenne WY 82001-3320	307-836-7785 dustin.kafka@us.army.mil	Site sponsor (Camp Guernsey)
Peter Nissen	Directorate of Environment and Natural Resources ATTN: Pete Nissen Building 810 Yakima Training Center Yakima, WA 98901	509-577-3500 Fax: 509-577-3336 peter.nissen@us.army.mil	Site sponsor (YTC)

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APPENDIX B

DECISION PAPER ON PUBLIC RELEASES FOR THE GERMPLASMS DEVELOPED UNDER THE SERDP AND ESTCP PROGRAMS

Antonio J. Palazzo, Kevin B. Jensen, and Susan E. Hardy

B.1 INTRODUCTION

The objective of this white paper is to provide a rationale for our choice of public releases as the most cost-effective and efficient method to get our plants in use on military lands. The germplasms were developed mainly under the SERDP/ESTCP programs during the last 8 years. Under the SERDP project SI-1103, we conducted basic and applied research to develop plant germplasms more resilient to military training activities. Under ESTCP project SI-0401, we are demonstrating the resiliency of these germplasms either alone or in mixtures on military lands.

B.2 PROJECT SUMMARY

We bred native and introduced plant species with modified traits related to resiliency and establishment on military lands. Our improved plant materials are ecologically compatible to military sites because they were developed on and from collections of species native to or previously seeded at these sites. We have published widely on various topics related to the concepts and methods, genetics, releases, and performance and resiliency of the species. Our studies on "ecological bridges" confirm that we can select seed mixtures that will establish more rapidly than all-native mixes, allow earlier land use for training, and ultimately lead to healthy and persistent stands of native plants. The species in the seed mixtures and the equipment needed are readily available and the seeding can be done in one application, thus saving money. Our modified germplasms will make these seeding mixes even more desirable.

The overall objectives of the projects were to:

- Breed modified native and introduced plant germplasms that have increased persistence and establishment characteristics under military training activities
- Understand the effects of training on soil compaction, plant injury, and regrowth
- Evaluate seeding methodology to better establish native and non-invasive non-native grasses in mixed stands while promoting resistance to invasion by non-native invasive plants.

B.3 BUSINESS PLAN

In 2002, we prepared a business plan describing our efforts to transfer this technology to commercial seed development so that the new plant materials and associated seeding methods may be readily available to military and other federal land managers. Our technology-transfer approach includes 1) demonstrating the advantage of the new germplasms and 2) developing a seed market for dispersal. To meet the demonstration objective, we established and monitored demonstration plots at selected installations to show the benefits of these new germplasms to

private and public land managers, users, and seed producers. For marketing, we have been giving presentations relating to plant establishment, management, and ecological parameters of the new germplasms.

B.4 MARKETING

Our marketing efforts for all the new germplasms are aimed at creating and promoting demand to show seed producers that it is commercially viable to produce the seed of these species. We have promoted the important beneficial characteristics of the species to military lands managers in the field, command managers, AEC, and other managerial types. To produce even more demand, we have also discussed the use of these with the Bureau of Land Management (BLM) and other federal agencies that purchase large quantities of seed. We have visited a seed production company and made a presentation to the National Seed Producers Association as well as at numerous professional meetings.

We anticipate that our work will provide a better return on the military investment. Within the range of distributions for the new germplasms, we have identified 42 DoD facilities, which include over 525 thousand hectares (1.3 million acres) of Army and Air Force land. The new germplasms are also appropriate for other federal, state, or local agencies; highway rights-of-way; mine spoils; rangelands; and other disturbed areas.

B.5 SEED PRODUCTION

In 2002 we contracted with the USDA-NRCS in Aberdeen, ID, to produce seed of three SERDP-developed species: western wheatgrass, slender wheatgrass, and Siberian wheatgrass. The initial seed production (~2000 lbs) will be distributed free to selected military installations in February 2007.

B.6 RELEASE PROCESS

All plant releases adhere to requirements set forth for publicly or privately released plant materials under a PVP agreement according to USDA-ARS and CRREL protocol. We propose that the seed be formally released in joint ownership with USDA-ARS (Forage and Range Research Laboratory [FRRL]) and Army (CRREL) with appropriate recognition given to SERDP for providing partial financial support in the development of these plant materials (see release notice write-up). Foundation seed will be produced and maintained by the USDA-ARS-FRRL and made available to the public for certified seed production through the Utah Crop Improvement Association.

B.7 PRIVATE VERSUS PUBLIC RELEASE

A major question now that the germplasms are close to being used in the field is to determine if they should be released publicly or privately. There are benefits and detriments with each method. The major benefit to a public release is that certified seed can be produced by any private seed grower without licensing. Directly related to the rapid acceptance of new revegetation (dryland) grasses on the market is the ability to have large amounts of seed available at the time of official release. The major draw back to a public release is the lack of advertising by one company trying to market the material. However, we do not feel that this

alone justifies a private (licensed) release of this material. A private release might produce royalties for seed sales to non-government entities, and it would allow us to control which seed companies receive the license to grow the seed, but that does not guarantee that the company will actually ever grow the seed for sale. Most seed produced through private-release government contracts is for use in limited areas. Seed producers are not accustomed to producing seed for the general market under government contracts. The amount of seed to be sold to the military is small compared to the entire market. There are greater sales potential for seed produced for grazing lands and reseeding after fires, and our new germplasms could be very useful for these demands. A public release appears to be the best method of insuring that our cultivars are produced and available for the widest possible market.

B.8 CONCLUSIONS

Regardless of whether seed is released publicly or privately, we can control the quality of the seed by requiring that only certified seed be produced via PVP protection. In considering all factors, it would be most cost-effective to the military, government, and private users to release these plant materials (cultivars only) publicly with PVP protection to ensure that only certified seed be sold on the market. Foundation seed for the production of certified seed can be obtained through Utah Crop Improvement Association.

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APPENDIX C

GERMPLASM RELEASE TYPES AND REQUIREMENTS

We prepared a white paper (Appendix B) describing the reasons for the various releases of the SERDP-select germplasms as a cultivar, source identified, selected, or tested class of germplasm. The conclusions of the white paper were: "Regardless of whether seed is released publicly or privately, we can control the quality of the seed by requiring that only certified seed be produced via PVP protection. In considering all factors, it would be most cost-effective to the military, government, and private users to release these plant materials (cultivars only) publicly with PVP protection to ensure that only certified seed be sold on the market. Foundation seed for the production of certified seed can be obtained through Utah Crop Improvement Association."

Four SERDP-select plant germplasms were released as cultivars with potential for PVP based on their breeding history and their response to selection for seedling vigor, persistence, and ability to regrow after disturbance. A minimum level of significance was set at alpha = 0.05, and SERDP-select materials were tested against these criteria.

The pre-variety germplasms require less or no testing to justify release. Pre-variety germplasm categories (AOSCA, 2003) are:

- Source-identified class: an unevaluated germplasm identified only as to species and location of the wild growing parents
- Selected class: germplasm shows promise of desirable traits, having been selected either within or as a common site comparison among accessions or populations of the same species
- Tested class: germplasm for which progeny testing has proven desirable traits to be heritable.

Progeny testing data for cultivar release must encompass two locations (environments) or two years of data. Additionally, an application for PVP Certificate (USDA form GR-470, at www.ams.usda.gov/science/pvpo/Forms/forms.htm) must include:

"Exhibit A. Breeding History. To include:

1. A full disclosure of the genealogy back to publicly known varieties, lines, or clones, including the breeding method;
2. The details of subsequent stages of selection and multiplication used to develop the variety;
3. A statement of uniformity reporting the level of variability in any characteristics of the variety (commercially acceptable variability is allowed);
4. A statement of genetic stability showing the number of cycles of seed reproduction for which the variety has remained unchanged in all distinguishing characteristics;

5. The type and frequency of variants observed during reproduction and multiplication.

“Exhibit B. Statement of Distinctiveness. This must clearly state how the application variety may be distinguished from other varieties of the same species. It must:

1. Identify the most similar variety or group of varieties and state all differences objectively;
2. Attach statistical data for characters expressed numerically and demonstrate that these are clear differences; and
3. Submit, if helpful, seed and plant specimens or photographs (prints) of seed and plant comparisons that clearly indicate distinctness.

“Exhibit C. Objective Description of the Variety. For example, resistance to disease, establishment rate, and plant persistence.

“Exhibit D. Optional Supporting Information. The applicant may provide additional information, specimens, and/or materials in support of the claims of the application.

“Exhibit E. Statement of Basis of Ownership.”

The general chronology for the release of a germplasm or cultivar is that a release notice, including release type and all supporting data, is first prepared for approval by the agency or agencies developing the plant material (in this case, ERDC-CRREL and the USDA-ARS). After their approval, the release notice is brought before the AOSCA or State Certification Board to get the material into the seed certification program. After approval of each release, we submitted an article to Crop Science or the Journal of Plant Registrations announcing the release.

Preliminary decisions about the appropriate release type for each SERDP-select population of plants as a cultivar or germplasm was based on breeding history, the unique differences observed in these plants in the later generations in the breeding process, and the potential demand in the marketplace. As we developed the plants, we adjusted release decisions for any and all germplasms based on the physiological and genetic data collected. We released the SERDP-select germplasms of western wheatgrass, slender wheatgrass, Russian wildrye and Siberian wheatgrass as cultivars, with release notices in 2006 through 2009; the final PVP application process is usually completed within 2 years. Because they are broad-based collections with little or no selective breeding applied, the Sandberg bluegrass and yarrow germplasms were released as either source-identified or selected-class pre-variety germplasms in 2004 or 2005. We used this demonstration program to advance our remaining germplasms as far as possible toward release as cultivars.

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